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Rapid Technology Assessment Framework for Land logistics

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ABSTRACT

This report follows the development of a Rapid Technology Assessment Framework (R-TAF). The framework is designed to assist with preliminary analysis of emerging technologies. It provides a requirements-centric approach to technology assessment as a balancing effort to what is often a technology-driven horizon-scanning process. The framework outlined in this document focuses on military Land logistics applications, although similar principles can be applied to other military domains.

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Executive Summary

Horizon scanning for emerging technologies is important in maintaining technological edge, taking advantage of new opportunities, and addressing emerging threats. However, it is a predominantly technology-focused process that can be prone to populist biases. The Land logistics Group horizon-scanning team sought to develop a Rapid Technology Assessment Framework (R-TAF) that would facilitate a more requirements-driven preliminary analysis of emerging technologies.

The framework considers three key questions for new technologies:

1. Is it useful to the client?
2. Is it better that the current solution?
3. What investment is needed to develop it into a capability?

This document follows the detailed deconstruction of these questions and their application to the requirements of Land logistics operations.

In considering the first question, we look at the enduring logistic effects as well as the impacts of expected operational environments. In doing so, our team put together an initial list of logistic effects, which were then refined in a workshop setting with military logistic Subject Matter Experts (SMEs). The SMEs further looked at a range of expected and wildcard operational environments and their effects on logistic operations. The resulting discussions helped us elicit the desired technology effects and technology characteristics for the various operational environments.

The second question considers any advantages that the new technology might have over the existing solutions. We examined this question in terms of the desired characteristics of logistic operations (such as responsiveness, flexibility, agility and sustainability), based largely on review of doctrinal publications.

Finally, the third question encompasses aspects such as development costs to mature the emerging technology, the initial acquisition and ongoing maintenance costs, and the expected technology integration requirements. The types of expected costs were largely taken from previous technology assessment reports.

We then bring this information together into an initial version of the R-TAF checklist that allows us to analyse the emerging technologies from a requirements-driven perspective. We illustrate the use of the checklist by applying it to hybrid generators - a technology of interest identified in a previous horizon scan for Land logistics.

This initial version of the R-TAF checklist is intended to assist us with analysis of technologies identified within the future technology scans. We will continue to refine and update it with iterative incorporation of client feedback.

Contents

Acronyms

ADDP	Australian Defence Doctrine Publication
ADF	Australian Defence Force
AI	Artificial Intelligence
ARE	Amphibious Ready Element
ARG	Amphibious Ready Group
AWD	Air Warfare Destroyer
C2	Command and Control
COP	Common Operating Picture
DFAT	Department of Foreign Affairs and Trade
DoD	Department of Defence (US)
EMS	Electromagnetic Spectrum
FAR	Field Anomaly Relaxation
FIC	Fundamental Inputs to Capability
FTA	Future-oriented Technology Analysis
GPS	Global Positioning System
HADR	Humanitarian Aid and Disaster Relief
ICT	Information and Communication Technology
IDP	Internally Displaced Persons
IED	Improvised Explosive Device
ISB	Intermediate Staging Base
IT	Information Technology
LF	Landing Force
LHD	Landing Helicopter Dock Ship
LIS	Logistic Information Systems
MA	Morphological Analysis
NEO	Non-combatant Evacuation Operation
NGO	Non-Government Organisation
NSB	National Support Base
OVP	Operational Viability Period
POW	Prisoners of War
R&D	Research and Development
ROE	Rules of Engagement
R-TAF	Rapid Technology Assessment Framework
RW	Rotary Wing
S&T	Science and Technology
SME	Subject Matter Expert
STEEP	Society, Technology, Economy, Environment, Politics
SWOT	Strengths, Weaknesses, Opportunities, Threats
TRL	Technology Readiness Level
US	United States
WHO	World Health Organisation

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1. Introduction

Horizon scanning of emerging technologies is a dangerous occupation – this technology-driven process fills one with the hope of great things to come. From 3-D printed organs to self-assembling asteroid-mining robots, the solution to all the world's problems is perpetually just around the corner. The imagination of business investors and the general public alike is captured by one technological breakthrough after another. Some breakthroughs help advance existing technologies. A select few become the next game-changers in society. However, the majority disappear from the social consciousness, failing to live up to their hoped potential.

Compounded with the inherent risk of researching cutting edge technologies is the context of financial austerity. With fewer resources, selecting which technologies to pursue becomes even more important. Which technologies warrant investment of public funds? Which ones will deliver the greatest utility across the range of possible future operational scenarios? Which ones will hold the greatest value-for-money potential?

For these reasons, a Rapid Technology Assessment Framework (R-TAF) was developed to assist analysts select the best technologies from a requirements-driven perspective. The document describes the development of a Rapid Technology Assessment Framework (R-TAF) designed for preliminary analysis of new technologies from a requirements-driven perspective. This rapid analysis would take place before any further investment of time and money into detailed impact assessments. Whilst the document focuses on Land logistics, the reader is invited to consider the broad applicability of similar frameworks to other military domains.

2. Conceptual Approach

Without immediately restricting the scope to military Land logistics, there are three fundamental questions that could be applied to any given technology or domain:

1. Is the technology useful?
2. Is it better than the current solution?
3. What investment is needed to develop it into an effective capability?

Figure 1 shows further conceptual breakdown of these three questions for the Land logistics domain.

1. **Is the new technology useful to logistic operations?**
   - Does the new technology enable required logistic effects?
   - Does it help achieve required capacity?
   - Does it alleviate or work within specific operational constraints?
   - Does it work within or alleviate key vulnerabilities?
2. **Is the new technology better than the current solution?**
   - Does the new technology increase responsiveness of logistic operations?
   - Does it reduce cost of logistic operations?
   - Does it increase flexibility and agility?
   - Does it reduce or optimise the logistic footprint?
   - Does it improve sustainability and robustness?
   - Does it facilitate situational awareness and total asset visibility?
   - Does it enable decentralised execution of mission?
   - Does it improve interoperability and deployability?
3. **What are the costs and Fundamental Inputs to Capability (FIC) for the new technology?**
   - How mature is the technology?
   - What are the initial acquisition costs?
   - What are the FIC and integration costs?

Figure 1: Conceptual breakdown that underpins the Rapid Technology Assessment Framework for Land logistics

The first question considers the enduring logistic effects that can be expected to remain relevant well into the future and certainly over the next twenty years. At the same time, however, it recognises that logistic effects are heavily affected by the operational context. Different operational environments influence the balance of logistic effects, capacity requirements, operational constraints, and points of vulnerability. For example, the logistic effect of providing sustenance to troops can be expected to remain a constant. Yet the operational environment will determine the type and quantity of rations, methods of procurement and distribution, and the relevant food handling processes. Logically, a new technology that provides sustenance should also help provide the required volumes of food or water and work within or alleviate the identified operational constraints and vulnerabilities.

The second question is broken down further in terms of the desired characteristics for logistic operations. A scholar of doctrine will recognise such terms as responsiveness, flexibility, agility and sustainability, which are used extensively within publications such as the *Australian Defence Doctrine Publication* (ADDP) 4.0 Defence Logistics [1]. An alternative way of looking at these sub-questions is in terms of the characteristics that allow one to assess the relevant advantages of the new technologies compared to the current systems. For example, if we are considering investment in a new technology that provides sustenance, we may consider whether it is faster/cheaper/less dangerous than trucking in ration packs and water. Does it perhaps allow for in-situ generation of water, thus reducing the number of convoys that would otherwise be exposed to interdiction?

The third question is considered in terms of the development costs, direct acquisition costs, ongoing maintenance costs, the costs of technology integration, and the associated infrastructure requirements. For instance, a new casualty treatment device that helps control bleeding can be incorporated into the combat health system with (primarily) only the costs of acquisition, replacement parts, and a small amount of training for the medical personnel. On the other hand, the development of an extensive additive manufacturing capability entails re-design of supply and maintenance processes, establishment of reliable supply chains, development of legal regulatory frameworks for liability, quality assurance and IP rights, and investment in local technical expertise and support. In other words, we would need an entire technical, commercial and procedural eco-system that is not yet fully developed in the civilian commercial setting.

This line of thinking forms the basis for further research and analysis in defining our technology assessment approach. If we were to apply this line of thought to a different military domain or to specific technology types, some of the terms would change to reflect the relevant system characteristics, but the fundamental conceptual approach would remain essentially the same.

3. Framework Development Method

The focus of this document is the development of an R-TAF for Land logistics. This type of framework falls into the broad category of forecasting and technology assessment studies used to support discussions of long-term strategies. Even a fairly brief survey of forecasting studies will reveal a plethora of conceptual approaches and techniques. An overview of some approaches is provided in Appendix . This appendix also describes in more detail the techniques used within this study, such as workshops, scenarios, wildcards, and focused technology scans. Figure 2 outlines how the specific methods were applied in elicitation of the relevant information for the Land logistics R-TAF.

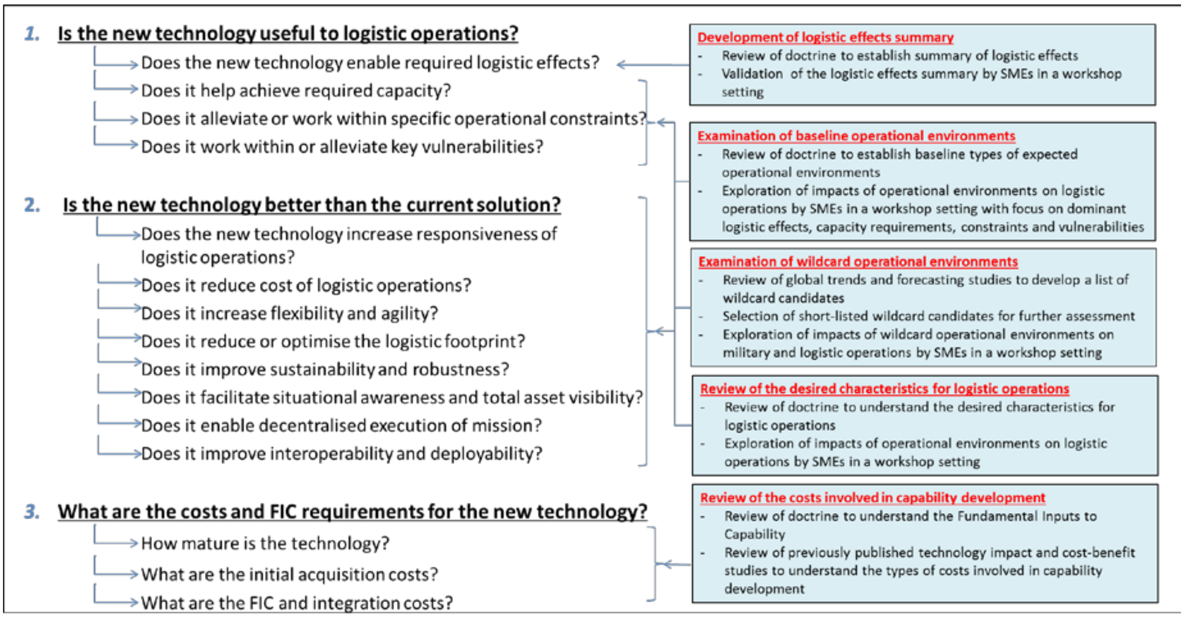

Figure 2: Overview of methods used in the development of the Rapid Technology Assessment Framework

The boxes within Figure 2 reflect the key activities within the framework development process. The next three sections of this document will focus on these in more detail and describe the findings. The reader is invited to follow the R-TAF development for the Land logistics domain whilst considering the potential for its application to other aspects of military operations.

4. Is the Technology Useful?

4.1 Establishing the Enduring Logistic Effects

Land logistics is as a system of systems that can be viewed in a number of ways; some examples are detailed in Appendix B. The doctrine-based draft list of enduring logistic effects developed for this study is an amalgamation of these perspectives with the use of the functional breakdown described in ADDP 4.2 (Logistic Support to Operations). It also incorporates the capability support functions outlined in ADDP 4.1 (Capability Support) and the overarching dimensions mentioned in ADDP 4.0 (Defence Logistics). More specific sub-functions are taken from ADDP 4.3 (Supply), ADDP 4.4 (Movements and Transportation), ADDP 4.5 (Materiel Engineering and Maintenance), ADDP 4.6 (Infrastructure Engineering and Maintenance), and ADDP 1.2 (Health Support to Operations). The structuring approach based on functions is chosen to make it easier to cross-match technology effects and to derive common trends in technology requirements. The initial draft list is outlined in Appendix C.

4.1.1 Finalised List of Enduring Logistic Effects

A panel of military logistics Subject Matter Experts (SMEs) within the Australian Army Headquarters were asked to review the draft framework in a workshop setting. The SMEs checked the proposed draft list to ensure appropriate structuring, scope and granularity. The resulting amendments incorporate re-allocation of several sub-functions, grouping of all logistic information systems under Command and Control (C2), incorporation of contract management aspects, and simplification of the health services sub-functions. In addition, a number of sub-functions such as mobility, counter-mobility and survivability support were identified as being outside the scope of Land logistics, and were removed from the list. Table 1 shows the finalised list of logistic effects for use within the R-TAF.

Table 1: Finalised list of enduring logistic effects

Logistic Function	Sub-functions
Supply	• Warehousing • Procurement • Demand forecasting • Inventory management and provisioning • Disposal of materiel • Waste disposal and management
Movements and Transport	• Preparation and planning • Terminal operations, including loading, unloading and cross-loading • Distribution: transport of personnel and materiel
Materiel Engineering and Maintenance	• Control of design, inspection, testing • Condition monitoring, calibration, servicing • Classification as to serviceability/engineering certification • Repair • Rebuilding • Modification • Reclamation • Overhaul • Recovery • Salvage/cannibalisation • Evacuation
Infrastructure Engineering and Maintenance – Sustainability Support	• Vertical and horizontal construction: planning, constructing and maintaining infrastructure • Provision of essential services • Obtaining resources in theatre • Waste disposal and recycling
Personnel Support Services	• Personnel administration • Postal services • Welfare services • Management of prisoners of war (POW) • Messing • Accommodation • Catering • Laundry • Shower services • Support to mortuary affairs
Health Services	• Prevention of injuries • Treatment of injuries • Casualty evacuation

Command and Control	• Logistic intelligence analysis in support of the Common Operating Picture (COP) • Maintaining situational awareness • Business intelligence and modelling for decision support • Tactical/operational/strategic planning • Tactical/operational/strategic communication • Control and coordination of specific logistic functions through Logistic Information Systems (LIS) • Development, application and measurement of doctrine, policy, structures, processes • Contract management
Capability Life-Cycle Management (in support of force modernisation and preparedness)	• Identifying capability gaps • Defining capability requirements • Acquiring and integrating capability • Managing fleet in service: rotation, deep maintenance, modification, monitoring fleet health status • Disposal of capability

This structuring of enduring logistic effects does not negate the fact that the various parts of the logistic system are intrinsically linked. For example, maintenance requires provision of repair parts through the supply chain; repairable and rotable supply items are in turn restored to serviceable condition through maintenance. Further interdependencies arise as some sub-functions can be listed against more than one logistic function, as is the case for loading and unloading. The concept of 'distribution' is sometimes used to encompass both the supply and transport functions.

4.1.2 Implications of Enduring Logistic Effects for Technology Assessment

Let's consider a new Technology XYZ. Within the proposed R-TAF approach, one of the first questions an analyst would ask when assessing the relevance of this technology is whether it facilitates a required function. So for military Land logistics, the analyst would check whether XYZ enables one or more of the functions listed in Table 1. Alternatively, he or she could consider whether XYZ eliminates the requirement for one or more of these functions.

This logic is straightforward, but it doesn't consider the implications of contextual environments. The operational setting affects the balance of logistic effects, determines the operational constraints and introduces specific vulnerabilities. Consequently, any new technology could only be considered useful if it facilitates logistic operations within the expected operational context. Exploration of operational contexts for logistic operations is therefore the subject of the next section.

4.2 Overview of Global Trends

Discussions of future operating environments are commonly based on projections of the global meta-trends across the physical, social and technological environments. Such discussions are numerous within both military and civilian publications. So while a more detailed analysis, citations and causal mapping are provided in Appendix D, only a brief summary is given below.

4.2.1 Physical Environment

In the physical domain, the global trends are dominated by concerns over climate change effects and a combination of over-population with urbanisation giving rise to poorly controlled mega-cities. Rising sea-levels and increasing concerns over global food, water and energy security are expected to lead to a growing significance of amphibious, littoral and urban operations. Furthermore, these operations are likely to take place concurrently in geographically diverse regions.

For logistics operations, this means a growing requirement for the development of small, modular units, potentially a growing number of concurrent operations and a requirement for robust on-shore/off-shore logistics with ship-to-shore connectors. Amphibious and littoral environments are becoming more and more significant for military forces. Additionally, environmental concerns and the pressure to reduce carbon emissions are likely to lead to development of alternative power sources and changes in the size of transportation platforms.

4.2.2 Human, Social and Political Environment

One of the most significant trends in this domain has been globalisation of the supply chains associated with reduction of local manufacturing. This has given us efficiencies and standardisation benefits, but has also created vulnerability to supply chain disruption.

At the same time, global instability has seen a rising number of failed and failing states with proliferation of non-state actors. The warfare type has been shifting between symmetric and asymmetric effects with the latter becoming more prevalent.

For logistic operations, the significant implication is the vulnerability of supply chains to asymmetric effects. In addition, the budgetary constraints entail an expectation of operational efficiency and leveraging of commercial services within military operations.

4.2.3 Technological Environment

In the technological space, the ever-present story of the last several decades has been the digitisation and increased interconnectedness of economic, government, social and communication systems. This has resulted in the emergence of cyber-enabled national enterprises. While enabling efficiencies and greater situational awareness across a range of processes, this trend has also lead to a critical dependency on the Information and Communication Technology (ICT) as well as significant vulnerability to cyber threats. The threats are pervasive, non-discriminatory, far-reaching and difficult to stop, with logistic systems being one of the potential targets.

Consequently, there is increasing recognition of the requirement for improvements in information management, handling, exploitation and assurance processes; development of resilient, protected networks; and signature and bandwidth management. Some logisticians also point to a need for avoiding over-reliance on ICT systems and for retention of the basic logistic skills.

The other big consequence of advances in ICT and sensor technology has been the emergence of the 'Internet of Things' concept and the dramatic increase in the quantity of available data across all spectrums of civilian and military processes. The quantity of available data has not yet been matched by the data analytics capability, but advances in this are being made.

The general profile of technological developments indicates a rapid rate of change and development with several potentially disruptive technological trends on the horizon. This, combined with the falling costs and barriers to technological innovation and reverse-engineering, has led to emergence of a protean enemy with ambiguous and unpredictable capabilities, and unconventional warfare with hybrid options. The threat posed by such an adversary is exacerbated by the declining Research and Development (R&D) and Science and Technology (S&T) budgets in the western nations leading to a gradual loss of technological edge.

For logistic operations, there is a great potential for leveraging off commercial technologies in supply chain management and automated transportation. However, the reduced S&T investment is expected to produce workforce challenges with gaps in mechanical engineering, aerospace maintenance and electronics.

4.3 Expected Operational Environments

4.3.1 Expected Operational Environments

Doctrinally, the operational environment is defined as 'the composite of the conditions, circumstances and influences that affect the employment of capabilities and bear on the decisions of the commander' [2] p. 1-9. The physical domains of the operational environment include maritime, land, air and space. The non-physical domains are information, electromagnetic spectrum (EMS) and human aspects.

For Australia, the expected operational environments are encapsulated within the Defence *White Paper*, which lists the ADF Principal Tasks as [3]:

1. Deter and defeat armed attacks on Australia
2. Contribute to stability and security in the South Pacific and Timor-Leste
3. Contribute to the military contingencies in the Indo-Pacific region with priority given to South-East Asia
4. Contribute to military contingencies in support of global security

Australian strategic culture has been to use the Army force elements in an expeditionary manner to achieve national political objectives with a strong emphasis on maritime strategy [4, 5]. This includes responding to tensions in times of peace, deterring aggression, peacekeeping, and fighting in joint and coalition operations [3]. The emphasis is on the ability to provide a rapid response to crises or threats (such as natural disasters, emergencies, armed threats) across the physical, electromagnetic and cyber dimensions [3].

Doctrinally, operational activities can be further divided into offensive, defensive and stability types [2]. They are often conducted as part of a coalition or in conjunction with other government departments.

Examination of a number of strategic documents [1-7] indicates that the following types of operations can be expected in the future:

Offensive

- Participation in general war, especially one involving Australia's national survival
- Deployment of joint task forces in the Indo-Pacific region and supporting the operations of regional partners (including amphibious operations)
- Special operations with low signature crisis response

Defensive

- Defence of Australian sovereignty against direct military threat or attack
- Protection of shipping/ freedom of navigation
- Terror attack response

Stability

- Humanitarian Assistance and Disaster Relief operations
- Peace-keeping/stability operations
- Civil community support in disasters and emergencies
- Assistance to civil authorities with border protection
- Counter-terrorism and counter-insurgency
- Evacuation of Australian and other nationals from hostile or crisis environments

4.3.2 Impact of Expected Operational Environments on Logistic Operations

Impact analysis for logistic operations was conducted in a workshop setting with military logistics SMEs from the Army Headquarters staff. Six examples were chosen from the above list to represent the wide range of operational environments that may require logistic support:

1. Civil community support in natural disaster
2. Humanitarian assistance and disaster relief (HADR)
3. Peace-keeping operations
4. Non-combatant evacuation operations (NEO)
5. Amphibious assault (as the principal type of amphibious operations)
6. General war on Australian territory

The SMEs were asked to analyse these baseline operation types in terms of the balance of logistic effects, capacity requirements, key constraints and vulnerabilities. The analysis took into account the more recent experiences of the Australian forces and other military forces across the world and incorporates key considerations stated in the relevant doctrine. (It should be noted that within the spectrum of operations between peace and war, there may be considerable overlap and transitioning requirements from one type of operation to another.)

Some characteristics identified as being common to all operations include constant media presence and political and diplomatic considerations. Logistic operations are always conducted with space, weight and lift capacity constraints. Situational awareness is universally important for asset tracking, communication and understanding of threats. Competition for limited assets such as rotary wing (RW) and land transport platforms can be expected to occur in most settings. Language and cultural barriers are common to all operations and apply not only to communication with local population and local authorities, but to interaction with coalition partners as well. Most military operations may expose participants to psychologically traumatic situations. Most military operations deal with challenging environmental conditions in terms of weather, terrain, and endemic diseases. All military operations require provision of food, water and shelter as a minimum. Further impact analysis of specific operational environments on logistic operations is discussed in more detail below.

4.3.2.1 Humanitarian Assistance and Disaster Relief Operations

Table 2: Analysis of Land logistics in the context of HADR operations

Humanitarian assistance and disaster relief (example: Operation Sumatra Assist in Banda Aceh, 2005)	
Balance of Logistic Effects	**Key constraints**
• Response is generally characterised by immediate austere response (finding victims, first aid), followed by recovery and reconstitution, including support to local authorities with information gathering • Hazard assessment teams are likely to go in first • Engineering support is likely to be required for building assessment in the initial phase • There tends to be greater demand for medical support • Support to local authorities includes gathering of information regarding the state of local settlements • There is generally reduced demand for classes 3 and 5 of supplies • There is usually little requirement for mortuary support • Self-sustainability, force preparedness and rapid projection are very significant, often with use of own lift assets	• Small logistic footprint is preferred for the initial response; fast response is essential • Deployed force structure may require use of specialists for general duties • There may be a requirement for segregation of own forces due to potential for exposure to diseases • The supply chains can be unpredictable with degraded capacity for local contracts and purchases • There are usually political and diplomatic constraints with curfews, and restrictions on the types of forces • Level of response may need to be adjusted to facilitate political perception management • There is always significant media presence • There are space constraints for equipment and infrastructure

Capacity Requirements	Points of Vulnerability
• Support to own forces (normally small tailored elements) • Limited support to civilian population, potentially numbering in thousands • Limited support to Non-Government Organisations (NGOs)	• The type of dependency for health support covers all demographics; this extends beyond the typically healthy and younger demographic of own forces • High potential for exposure to pathogens • Psychologically traumatic environment for own forces and local population

An analysis of Land logistics in the context of HADR operations is given in Table 2. HADR operations generally start with an initial rapid response that focuses on finding victims and provision of first aid, sustenance and shelter. This needs to happen quickly, cover the basic needs of the victims and be done with a small logistic footprint. Later, the ADF may be required to assist with more specialised support and reconstitution tasks, as well as development of situational awareness on the state of local settlements. There is a high risk of exposure to dangerous pathogens, which requires initial deployment of hazard assessment teams. Furthermore, in the case of disaster relief, damage to local infrastructure introduces a requirement for early engineering safety assessments. As can be expected, medical support plays a significant role (although not usually mortuary support). Characteristically for HADR operations, medical support is expected to cover all demographics of local population including women, children, elderly, and people with pre-existing conditions. The operations are constrained by unpredictable supply chains, heavy media presence and ongoing political negotiations.

Desirable characteristics for technologies in this setting are light weight, small size, and rapid deployability. These technologies need to operate in environmentally challenging conditions and assist with self-sustainability for transport, sustenance, infrastructure and supplies. Rapid access to specialised support may be desirable in medical emergencies, as is technology that enables rapid and high-volume sterilisation and cleaning of equipment, vehicles and consumables. Furthermore, protection from diseases becomes a highly-desirable effect. Technologies that provide situational awareness without reliance on RW platforms are desirable, and technology design needs to take into account political and cultural sensitivities.

4.3.2.2 Civil Community Support in Natural Disaster

Table 3: Analysis of Land logistics in the context of civil community support operations

Civil community support in natural disaster (example: Assistance to local population following Cyclone Larry, 2006)	
Balance of Logistic Effects	**Key constraints**
• Civil support in natural disaster is essentially a HADR type operation, but with greater access to the National Support Base (NSB) support • Focus is mainly on logistics; no warfighting effects are required • Military supply chain may be using government-provided stocks for aid to civilian population • Infrastructure engineering tasks may include clearance, sanitation, provision of power and site survey tasks	• Perception management is important, as there is a tendency to look to the military for leadership in these situations • Collaboration with state emergency response systems is essential

• Provision of water, sustenance may be required • Health support is less essential due to availability of national infrastructure	
Capacity Requirements	**Points of Vulnerability**
• Mostly support to own forces is required • Small requirement for feeding and protecting local population	• Damage to local infrastructure and buildings

An analysis of Land logistics in the context of civil community support in natural disasters is shown in Table 3. Civil community support in natural disaster can be considered a type of HADR operation that takes place on Australian soil. This presents the advantage of easy access to NSB support, infrastructure and supply chains. The tasks mainly involve clearing and assessing structures, provision of food and sanitation, and collaboration with state emergency response teams where required.

Technology of use in this setting would be those facilitating infrastructure engineering tasks, situational awareness, and provision of sustenance.

4.3.2.3 Peace-Keeping Operations

Table 4: Analysis of Land logistics in the context of peace-keeping operations

Peace-keeping operations (example: Operation Astute in East Timor, from 2006)	
Balance of Logistic Effects	**Key constraints**
• Slightly larger war-fighting dependency compared with HADR operations • More enduring nature of logistic support with long-term presence • Initial requests for support may be logistic in nature, e.g. medical support, air-lift, engineering, movement control • Increased use of military vehicles for distribution tasks • Increased use of RW assets for distribution and force projection • Health intelligence is important for preventing exposure to environmental threats • Leveraging of host nation support infrastructure is done where possible • Some coalition support may be available • Interoperability and ability to leverage support partners' capabilities are very important • Significant requirement for LIS/knowledge management systems • Support to Civil-Military Co-operation (CIMIC) tasks may be required	• There may be a requirement to work in information-poor environments • Language and cultural barriers can be expected, not just with local population but also with coalition partners • Requirement for standardisation for interoperability • Limited civilian infrastructure
Capacity Requirements	**Points of Vulnerability**
• Capacity requirements are likely to be scaled; they may range from support to own elements to supporting a multinational force • Limited assistance/support to civilian	• There can be very rapid transition across the spectrum of peace-keeping to peace-enforcement with varying degrees of military intervention; this affects consumption rates, security

population and Internally Displaced Persons (IDPs) (in conjunction with NGOs) who may number in thousands • Maintaining surge capability is important so as to meet new demands rapidly	requirements, holding policies, tempo of operations, etc. • There is a high potential for exposure to endemic pathogens

An analysis of Land logistics in the context of peace-keeping operations is shown in Table 4. Peace-keeping operations have some characteristics in common with HADR operations, but they tend to involve a larger (often multi-national) and longer-term presence. Interoperability requirements come to the fore with logistic support functions balanced across the various coalition partners. Support may be required for own and partners' elements, with potential for limited assistance to local IDPs. These factors bring to the fore the cultural and language barriers that exist not only between Australian forces and the local population, but also between coalition partners. Health intelligence for disease prevention remains important due to a high risk of exposure to endemic pathogens. The space constraints for logistic footprint are not as pressing as for some other operational environments.

A key characteristic of peace-keeping operations for logistics is the potential for rapid transition across the spectrum from peace-keeping to peace-enforcement with varying degrees of military intervention. This affects consumption rates, security requirements, provisioning, and tempo of operations. Hence, adaptability, responsiveness and surge capacity are very important.

For technology requirements, environmentally challenging conditions remain. Technology characteristics such as standardisation across coalition technologies and processes become more significant. Detection and protection from diseases is a desirable effect, as is anything that helps overcome language and cultural barriers. Technologies that improve responsiveness through faster re-supply and distribution, local production, and capacity redundancies are also of increased value in this environment.

4.3.2.4 Non-combatant Evacuation Operations

Table 5: Analysis of Land logistics in the context of non-combatant evacuation operations

Non-combatant evacuation operations (example: Operation Spitfire, Dili, 1999)	
Balance of Logistic Effects	**Key constraints**
• Main elements of the operation are establishment of beach head, protection and extraction • Tasks generally include securing, sorting and evacuating the non-combatants; next level of processing and support may be expected at Intermediate Staging Base (ISB) or NSB • Leveraging of commercial industry is expected • Immediate response covers minimal requirements; types of supply mix would include Class 1 and small amounts of Class 8 • Some specialised types of support may be required, such as veterinary support • Provisioning may be required for non-military stores with establishment of local contracts at	• Minimal logistic footprint is preferred • Operations may have to be conducted without the support of local authorities • Limited combat forces • Extended lines of communication • These operations would be normally led by the Department of Foreign Affairs and Trade (DFAT) • The operations are likely to be short-notice • Response is calibrated to political environment; diplomatic considerations affect Rules of Engagement (ROEs), carriage of weapons, etc. • Limited or non-existent supply chain with requirement for short-term self-sufficiency

short notice	
Capacity Requirements	**Points of Vulnerability**
• Support to own forces which are typically small elements • Support to evacuees who may number in the thousands • There may be concurrent HADR operations taking place	• Spectrum of threat level can range from benign to hostile and may change rapidly • Non-combatants distributed over a wide geographic area may be a point of vulnerability • There is potential for medical emergencies requiring specialist intervention (e.g. obstetric, paediatric)

An analysis of Land logistics in the context of non-combatant evacuation operations is shown in Table 5. NEO can take place in environments ranging from largely benign to overtly hostile situations without support of the local authorities. They tend to be short-term operations that happen at short notice and are typically DFAT-led. Diplomatic and political relationships play a large role in determining the ROE and carriage of weapons, but military elements are typically restricted to the minimal possible footprint. The military is generally expected to assist with securing, sorting and evacuating Australian and Approved Foreign Nationals. More extensive support may be expected subsequently at the ISB or NSB. Logistics in this setting are characterised by a focus on the basic requirements and health support, limited supply chain availability, and establishment of local contracts at short notice. The evacuees may be spread across a large geographic area, which is a point of vulnerability in more hostile environments. Additionally, the wide demographic spread of evacuees presents potential for medical emergencies requiring specialist treatment, such as obstetric or paediatric emergencies.

Some technological characteristics of value in this setting are similar to those for HADR, such as facilitating access to specialist medical support. At the same time, technologies enabling rapid transportation of personnel across diverse geographic terrain become useful, as do any technological solutions that help minimise the logistic footprint.

4.3.2.5 Amphibious Assault Operations

Table 6: Analysis of Land logistics in the context of amphibious assault operations

Amphibious assault operations (example: Reconquest of New Guinea, WWII)	
Balance of Logistic Effects	**Key constraints**
• Logistics over the shore define the operations, with use of maritime and air transport assets • Self-sustainment is likely to be required for initial Operational Viability Period (OVP), with external re-supply/sea-basing for more extended operations • Generally, amphibious operations tend to be short-term	• Amphibious operations take place across several environments: blue-water, green-water, and land with limited entry points • Weight and space restrictions apply • Lift capacity restrictions apply for any transfers over the shore • Tidal window restrictions apply to maritime transport assets • Maritime approaches are generally required for

	re-supply • The ship effectively becomes an 'island'; this makes transportation of e.g. casualties more difficult • There is ongoing competition for transportation assets with more pronounced tensions between combat force projection and logistics concerns • Increased emphasis on prioritisation of assets with consideration of the maritime fleet requirements • There is competition between different supply chains, including one for maritime forces • Loading sequence becomes important as it determines the sequence for unloading
Capacity Requirements	**Points of Vulnerability**
• Own force size dependency will vary from Amphibious Ready Element (ARE) to Amphibious Ready Group (ARG) with the latter more likely being part of a coalition force • Dependencies may extend beyond the Landing Force (LF) component, depending on the operational aims • In environment of increased threat, additional assets can be expected to be deployed e.g. AWDs	• Sea states are likely to have significant impact on logistic capability • Extended lines of communication • In situations of increased threat, the ship is likely to leave the area and move over the horizon. This extends lines of communication for logistics, reduces responsiveness and potentially leaves some elements stranded

An analysis of Land logistics in the context of amphibious assault operations is shown in Table 6. Amphibious operations tend to be short-term with the size and nature of the force tailored to the task. This can range from smaller ARE deployment with one Landing Helicopter Dock (LHD) ship to full ARG deployment with two LHDs and a number of additional maritime and air assets. These operations are inevitably Joint in nature. Space and lift capacity restrictions heighten the need to balance the competing requirements of own elements. Competition is likely to take place between maritime force requirements and supply chains and the LF needs, as well as between combat force projection and logistic concerns.

Amphibious operations call for logistics over the shore and any assets and consumables for use on the ground need to be transported over water, as do casualties being brought back to the ship(s). This type of operation is therefore highly susceptible to adverse weather and highly dependent on tidal windows. If the key LHD platforms move over the horizon due to increased threat levels, the already extended lines of communication and distribution may become disrupted, stranding elements on the ground.

Technology solutions of value in this setting are those that reduce volume and weight of required materiel, and facilitate or reduce distribution requirements over the shore. They may be required to operate in challenging weather conditions and facilitate communications, situational awareness and distribution tasks over long distances. In cases of temporary unavailability of key supporting platforms, technologies that facilitate self-sustainment and casualty stabilisation for ground forces become important. In addition, technologies of value need to be adaptable to a range of opportunistic platforms, work across the full range of blue-water/green-water/land environments, and be multi-modal. For inventory management, technologies that facilitate tracking and location of materiel

within the ship become useful. Technologies that are to be used aboard the ship need to be compatible with the ship's systems.

4.3.2.6 General War on Australian Territory

An analysis of Land logistics in the context of general war on Australian territory is shown in Table 7. A war on Australian territory would place a higher emphasis on support to combat operations with provision of Classes 1, 3 and 5 becoming more significant. At the same time, the operations would be expected to have a high tempo, involve multiple engagement locations and require rapid traversing of long distances. In a general war scenario, the attack would likely happen in the physical as well as the cyber domain. Furthermore, it is not only the military forces that are targets, but civilian population and infrastructure as well. Since the whole nation would be mobilised to assist with the war effort, logistic operations would be integrated with use of civilian suppliers, health facilities, transportation and manufacturers.

The key point of vulnerability for Australia in this scenario is its critical dependency on the global supply chain for most processed consumables, from food to medications. In particular, there is little indigenous oil refining capability and the current holdings within the country would be used up in a matter of days. Local manufacturing is limited and specialised, which makes it difficult to re-purpose for military use.

Table 7: Analysis of Land logistics in the context of general war on Australian territory

General war on Australian territory[1] (example: Bombing of Darwin, WWII)	
Balance of Logistic Effects	**Key constraints**
• All facets of logistics provision would be fully engaged • Support to combat operations in provision of classes 1, 3 and 5 become of particular importance • Health footprint forward may be reduced if air routes are still viable • High level of movement is to be expected, with potentially multiple engagement locations	• Contested environment • Access, roads and long distances are likely to become an issue • There is generally greater access to supply from within the country • Fast tempo of operations
Capacity Requirements	**Points of Vulnerability**
• Whole of government involvement would apply in this case, with national mobilisation • Support to own forces, most of which would be mobilised • Some assistance to affected civilian population and IDPs who may number in the thousands	• Australia is very vulnerable to supply chain disruption; re-purposing of local manufacturing for military roles may be difficult due the niche and specialised nature of in-country manufacturing capability • Energy and fuel are the most critical points of vulnerability; there is a lack of indigenous capability for processing oil • Denial of routes (including medical and civilian supply chains), Improvised Explosive Devices (IEDs), etc. are points of vulnerability

[1] The SME discussion in this case considered a hypothetical case of peer-matched (rather than asymmetric) warfare.

	• Vulnerability of ICT systems to jamming/satellite warfare/cyber-attacks • Key civilian infrastructure may become targets: electrical stations, water treatment plants, etc.

Specialised technological solutions such as the various casualty treatment applications would have extensive use in this setting. However, in a more holistic sense, any technology that reduces dependence on global supply chains and oil, and that reduces vulnerability of key infrastructure as targets, would be of value not only to military operations and logistics, but to national security in general. Technology that facilitates rapid distribution of materiel and forces across large distances would be of particular value in an Australian setting. ICT-dependent technological solutions need to be resistant to cyber-attacks or capable of independent operations.

4.3.3 Implications of Operational Contexts for Technology Assessment

The impact analysis presented in the previous sections highlights some common and specific constraints and operational requirements. Table 8 presents a summative analysis of implications for technology selection and design.

Table 8: Effects of operational contexts on technology requirements

Operation type	Requirement	Desired technology characteristics	Desired technology effects	Currently known emerging technological solutions
All	Work within and/or alleviate space, weight and lift capacity constraints to reduce competition for key assets	• Lightweight and strong • Small in size • Multi-functional	• Reduce stockholding requirements • Reduce resupply requirements • Reduce dependence on limited transportation platforms • Replace humans where possible, especially for dull, dirty or dangerous tasks • Enhance human capability	• Local production/processing /generation of resources including fuel, power, food, water, spare parts • Extension of shelf-life and storage range of consumables • Alternative distribution mechanisms with use of smaller autonomous systems (smaller quantities more frequently) • Replacement of humans with autonomous robotic systems • Use of enhancing systems such as powered exoskeletons
All	Maintain situational awareness of assets, personnel, threats, local population and infrastructure	• Sensor-enabled • Networked • Robust/Redundant • User-friendly	• Maintain or improve situational awareness (logistics and beyond) • Gather, transmit and analyse data of various types • Incorporate data into decision-support applications • Facilitate data processing by operators and decision-makers • Enable communication across extended distances • Facilitate/augment data assimilation and interpretation by the users	• Use of sensors, networks and big data analytics for 'Internet of Things' applications • Various types of sensors for environmental, biological, and hazard monitoring • Use of GPS-enabled tracking systems • Use of autonomous systems for creation and optimisation of local communication networks • Use of augmented cognition systems for optimisation of data feed to users
All	Alleviate language and cultural barriers	• Designed to account for cultural sensitivities	• Facilitate translation • Facilitate cultural awareness • Facilitate/augment data assimilation and interpretation by the users	• Speech recognition and translation technologies • Immersive training solutions

Operation type	Requirement	Desired technology characteristics	Desired technology effects	Currently known emerging technological solutions
All	Prevent and treat psychological trauma	• Designed to account for the psychological state of the user	• Detect/assess the situational potential for psychological trauma • Replace humans for potentially traumatic tasks • Facilitate warnings and preventative measures before psychological trauma is incurred • Facilitate diagnosis and treatment • Facilitate access to specialist support • Facilitate/augment data assimilation and interpretation by the users	• Replacement of humans with autonomous robotic systems for potentially psychologically damaging tasks • Neurocognitive diagnostic technologies • Telemedicine technologies
All	Protect from endemic diseases	• Predictive • Protective/ preventive • Enabling rapid response	• Provide situational awareness on emerging health threats • Analyse trends to detect emerging threats • Detect pathogens and hazardous substances • Rapidly identify pathogens and hazardous substances • Provide decision-support for threat mitigation • Protect personnel from pathogens and hazardous substances • Treat personnel post-exposure • Facilitate cross-exposure control measures	• Bioengineering applications in design of vaccine and treatments • Bioengineering applications in pathogen identification • Blood filtration technologies • Various biological and environmental sensors for early threat detection
All	Operate within challenging environmental conditions and contested environments	• Robust • Flexible and adaptable • Resistant to cyber attacks • Easy to repair or replace	• Improved personnel protection/comfort, reduced exposure to the challenging environment • Reduction in the perceived challenge • Improved robustness of critical infrastructure and systems	• Replacement of humans with autonomous robotic systems for 'dull, dirty and dangerous' tasks, such as logistics transport and materiel handling functions

Operation type	Requirement	Desired technology characteristics	Desired technology effects	Currently known emerging technological solutions
NEO, HADR	Deploy on very short notice	• Rapidly deployable • Easily accessible, packable, transportable • Small in size • Lightweight	• Improve preparedness for deployment (planning, situational awareness) • Improve and maintain situational awareness • Facilitate tailoring of logistic effects	• Advances in in-situ water filtration, power generation, fuel generation technologies • Additive manufacturing/3-D printing of selected spare parts in-situ where appropriate
NEO, HADR	Establish access to specialist support in isolated locations	• Working with limited bandwidth availability • Distributed access	• Provide effective communications link to specialists in a different geographic location • Partly of fully replace human specialists	• Telemedicine/telemaintenance technologies • Telecommunication options • Replacement of human specialists with partly or fully autonomous specialised robotic systems
HADR	Rapid high-volume cleaning and sterilisation	• Small, lightweight, portable • Able to work in a multitude of environmental conditions	• Provide rapid high-volume sterilisation/ cleaning capability for equipment, platforms, consumables and personnel	• Use of carbon nanotubes for rapid steam generation from sunlight • Improved nanomaterials for equipment coatings, including with anti-bacterial and other desirable sterilisation properties.
HADR, amphibious operations	Self-sustainability for transportation, sustenance and health support with small logistic footprint	• Small in size • Lightweight • Multifunctional	• Provide sustenance, power and health support with minimal footprint and transportation requirements • Facilitate force self-sustainability	• Local production/processing /generation of resources including power, food, water, spare parts • Extension of shelf-life and storage range • Alternative distribution mechanisms with use of smaller autonomous systems (smaller quantities more frequently) • Replacement of humans with autonomous robotic systems • Telemedicine technologies • Telecommunication options • Replacement of human specialists with partly or fully autonomous specialised robotic systems

Operation type	Requirement	Desired technology characteristics	Desired technology effects	Currently known emerging technological solutions
Peace-keeping	Interoperability with coalition partners	• Standardised with coalition partners' equipment, processes and information exchange systems	• Enable technological interfaces between systems with different structures, designs and standards • Facilitate information exchange between systems with different designs	• Increased adoption and utilisation of open architectures and open standards for interoperability, e.g. General Vehicle/Base/Soldier Architectures
Peace-keeping	Surge capacity	• Flexible and adaptable • Extensible and scalable • Fast-responding • A degree of redundancy	• Facilitate rapid surge capability • A buffering effect on rapidly escalating/de-escalating demand	• Faster/alternative re-supply modes • Local production/processing /generation of resources including power, food, water, spare parts • Redundancy in capacity • Scalable production/ processing capability • Provisioning algorithms
Amphibious operations, NEO, general war	Ability to operate with extended lines of communication (including distribution and transportation)	• Flexible and adaptable • Extensible and scalable	• Facilitate communication over extended distances • Facilitate distribution over extended distances • Facilitate transportation of personnel (including casualty evacuation) over extended distances	• Use of autonomous systems for creation and optimisation of local communication networks • Alternative distribution mechanisms with use of smaller autonomous systems (smaller quantities more frequently) • GPS-based systems for tracking of assets and personnel • Autonomous casualty evacuation technologies
Amphibious operations, general war	Casualty stabilisation to extend the 'golden hour' window	• Interoperable with a range of opportunistic platforms • Portable, lightweight • Rapidly implementable	• Stabilise casualty for extended periods of time • Provide life-saving surgical treatment in austere conditions • Replace human operators thus reducing the number of casualties • Provide evacuation options where other platforms are not available	• New haemorrhage control technologies • Artificial slowing of metabolic rate • Artificial blood products • Robotic surgery • Telemedicine technologies • Replacement of human operators with autonomous robotic systems • Autonomous casualty evacuation technologies

Operation type	Requirement	Desired technology characteristics	Desired technology effects	Currently known emerging technological solutions
General war	Reduce dependency on global supply chain	• Independent of global supply chain	• Reduce dependency on overseas supply of manufactured parts, food and water, oil and fossil fuels • Improve organic/indigenous capabilities for the production of the above	• Local production/processing /generation of resources including power, food, water, spare parts • Optimisation of fuel and energy use through controlled hybrid options • Improved flexibility in manufacturing capability through additive/adaptive manufacturing technologies
General war	Reduce vulnerability of key civilian infrastructure	• Distributed in nature • Resilient/robust • Some degree of redundancy • Difficult to destroy in targeted attacks • Resistant to cyber attacks	• Provide power, energy and other outputs/services of key civilian infrastructure in a distributed manner • Reduce reliance on ICT connected systems for essential services	• Use of distributed sources of power and energy such as solar power • Development of more robust networks capable of opportunistic synchronisation
All	Capacity requirements vary from support to very small own and/or civilian elements to sustainment of much larger force and assistance to civilian population numbering in thousands with potentially rapid surges in demand	• Flexible/scalable capacity	• Provide for rapid surges in demand	• Local production/processing /generation of resources including fuel, power, food, water, spare parts • Extension of shelf-life and storage range of consumables • Alternative distribution mechanisms with use of smaller autonomous systems (smaller quantities more frequently)

It is unlikely that a military organisation would keep separate sets of equipment for different types of operations. Hence, our approach here is to summarise the prevalent desired technology characteristics and technology effects and to use these as part of the R-TAF assessment checklist. The technology effects can be added to Table 1 to provide more specific requirements, as shown in Table 9. A summary of the recurring desired technology characteristics for baseline operational environments is given separately in Table 10.

Table 9: Augmented list of enduring logistic effects

Logistic Function	Sub-functions	Desired technology effects
Supply	• Warehousing • Procurement • Demand forecasting • Inventory management and provisioning • Disposal of materiel • Waste disposal and management	• Reduce stockholding and resupply requirements • Reduce dependence on limited transportation platforms • Facilitate force self-sustainability • Facilitate rapid surge capability • Reduce dependence on global supply chains • Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability
Movements and Transport	• Preparation and planning • Terminal operations, including loading, unloading and cross-loading • Distribution: transport of personnel and materiel	• Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability
Materiel Engineering and Maintenance	• Control of design, inspection, testing • Condition monitoring, calibration, servicing • Classification as to serviceability/engineering certification • Repair • Rebuilding • Modification • Reclamation • Overhaul • Recovery • Salvage/cannibalisation • Evacuation	• Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability • Facilitate access to specialist support • Reduce maintenance requirements
Infrastructure Engineering and Maintenance – Sustainability Support	• Vertical and horizontal construction: planning, constructing and maintaining infrastructure • Provision of essential services • Obtaining resources in theatre • Waste disposal and recycling	• Improve robustness of critical infrastructure and systems • Provide power and energy as well as other key services in a distributed manner • Reduce reliance on ICT connected systems for essential services • Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability • Facilitate access to specialist support

Logistic Function	Sub-functions	Desired technology effects
Personnel Support Services	• Personnel administration • Postal services • Welfare services • Management of POW • Messing • Accommodation • Catering • Laundry • Shower services • Support to mortuary affairs	• Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability
Health Services	• Prevention of injuries • Treatment of injuries • Casualty evacuation	• Extend evacuation options and time windows for casualties • Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability • Facilitate access to specialist support • Facilitate prevention, diagnosis and treatment of psychological trauma • Facilitate detection, identification, protection and treatment in relation to hazardous substances • Facilitate cross-exposure control measures • Reduce personnel exposure to environmental extremes
Command and Control	• Logistic intelligence analysis in support of the Common Operating Picture • Maintaining situational awareness • Business intelligence and modelling for decision support • Tactical/operational/strategic planning • Tactical/operational/strategic communication • Control and coordination of specific logistic functions through LIS • Development, application and measurement of doctrine, policy, structures, processes • Contract management	• Maintain or improve situational awareness through gathering, transmission and analysis of data • Facilitate tailoring of logistic effects • Facilitate decision support for strategic/operational/tactical planning and C2 • Enable communication across extended distances • Facilitate preparedness for deployment • Enhance human capability • Facilitate data processing by operators and decision-makers • Facilitate communication across cultural/language barriers • Facilitate access to specialist support
Capability Life-Cycle Management (in support of force modernisation and preparedness)	• Identifying capability gaps • Defining capability requirements • Acquiring and integrating capability • Managing fleet in service: rotation, deep maintenance, modification, monitoring fleet health status • Disposal of capability	• Maintain or improve situational awareness through gathering, transmission and analysis of data • Facilitate tailoring of logistic capability • Facilitate decision support for strategic planning and C2

Table 10: Summary of the commonly desired technology characteristics for baseline operational environments

Type of technology characteristic	Desired technology characteristics
Physical	• Lightweight • Robust to physical stress and range of environmental conditions • Small and portable • Rapidly deployable: easy to procure/access, pack and transport • Easy to repair/ replace • Distributed in nature
Functional	• Multi-functional, flexible, adaptable • Scalable in effect • Incorporating redundancies • Sensor-enabled and networked • Predictive • Working within limited bandwidth availability • Resistant to cyber attacks
Interface	• Designed with awareness of cultural sensitivities • Cognisant of operator state • Reactive to operator state • Protective/ preventive • Enabling of decision support and rapid response • Standardised for joint and coalition operations • Interoperable with a range of opportunistic platforms

The two tables above provide checklists that can be applied to assess the usefulness of new technologies. The next section refines these further with consideration of possible wildcard scenarios.

4.4 Impacts of Wildcard Scenarios

4.4.1 Wildcard Candidates

Wildcards refer to low probability – high impact events that occur rapidly, giving the system little chance to adapt [8, 9]. Comprehensive methodology for wildcards can be found in [10] with shorter overviews in [8, 9] and a brief overview in Appendix A.3.5. Wildcards are useful in overcoming possible blind-spots and shortcomings of the trend-driven foresight that was used above [8]. They can also help develop early warning systems and monitor for indicators of the change [9].

Wildcard candidates for the development of the R-TAF were collected from various forecasting reports and initiatives and from analysis of global trends. The identified wildcard candidates and references are summarised in Appendix E within groupings according to their origin using the STEEP sectors: Society, Technology, Economy, Environment, Politics [8]. Overview of the candidates list suggests that the currently anticipated wildcard scenarios are becoming increasingly broad and global in nature due to ICT connectivity and globalisation, with some being more extreme extrapolations of the current trends.

In the initial filtering of candidates we considered the likelihood, rate of change, expected level of surprise and relevance to involvement of military forces. In addition, some wildcards with similar effects were aggregated. The resulting shortlist of wildcard candidates is presented below. In the list below, the citing of 'A' indicates that the wildcard was the result of analysis of the global trends picture.

1. Instability/crime/revolt leading to violent outbreaks within a regional mega-city [A][8] with population no longer recognising political authority [11].
2. Outbreak of global war over control of diminishing resources [12] with most of the world's satellites destroyed or disabled [A].
3. Coordinated terrorist attacks on logistic networks and physical choke-points lead to global supply chain crisis [A] [13].
4. Combination of nano-technology, exploitation of swarming algorithms and directed energy weapons leads to significant changes in the nature of warfare and battle-space [A][8, 14].
5. Combination of research efforts into artificial intelligence (AI) and transfer of human consciousness results in development of self-aware AI entities that effectively take control of ICT-enabled systems [8] [11]
6. Combination of over-population, climate change effects and untempered consumerism lead to shortages of food, water, energy and environmental resources across the globe [A][8, 11, 12, 14, 15].
7. Climate change reaches tipping points leading to severe climate shocks, rising sea levels, mass migrations and resource shortages – 'threat multiplier' effect [A] [8, 11, 13, 15, 16].
8. Mutation of a known pathogen renders it highly virulent, air-borne and lethal to humans with 7-21 days incubation period. Global travel networks result in the spread of the pathogen to most parts of the world including Australia, before the outbreak can be contained. Treatment options are limited [A] [8, 11-13, 15, 17, 18].
9. Major geological/meteorological event, such as asteroid strike or volcanic eruption occurs on the Australian territory [8, 11-13, 15, 17].

4.4.2 Impacts on Military and Logistic Operations

As part of the workshop with military logistic SMEs, we asked the participants to consider some background material for each of the scenarios and perform an initial impact assessment using the scorecard shown in Table 11. This impact assessment scorecard has been adapted from that in [8] by removing impact factors that only apply to wildcard scenarios with positive effects (as we are only considering wildcards with negative effects). The assessment scores for each impact factor were also adjusted to range from 1 to 5 for consistency of assessment. This impact assessment considers effects on Australia as a whole.

The participants also considered the possible roles for military forces and the implications for logistic operations. The results of impact assessment and key discussion points are summarised in Table 12.

Table 11: Impact assessment scorecard used for wildcard scenarios (adopted from [8])

IMPACT FACTORS	ASSESSMENT
RATE OF CHANGE (ΔC) Faster change = More impact	1 – 2 – 3 – 4 – 5 Years (1), Months (3), Days (5)
REACH (R) Wider reach = More impact	1 – 2 – 3 – 4 – 5 Local (1), Global (5)
VULNERABILITY (V) Less adaptable = More vulnerable	1 – 2 – 3 – 4 – 5 Less vulnerable (1), More vulnerable (5)
OUTCOME (O) More uncertainty = More impact	1 – 2 – 3 – 4 – 5 Less impact (1), More impact (5)
TIMING (T) Later events = Better outcome	1 – 2 – 3 – 4 – 5 2035+ (1), 2030-2035 (2), 2025-2030 (3), 2020-2025 (4), 2015-2020 (5)
POWER FACTOR (P) More individual effect = Stronger impact	1 – 2 – 3 – 4 – 5 Weaker impact (1), Stronger impact (5)
TOTAL	

Table 12: Impact assessment and effects on logistic operations for wildcard scenarios

Wildcard scenario	Average impact score / 30	Effects on Australia, military operations and logistics
1. Instability in mega-cities	21.2	• This is likely to take place in the Indo-Pacific rather than Australia • All mega-cities are different and some function well; they tend to be hybrid structures with formal and informal components • Some parts of mega-cities may be 'self-governed' by criminal organisations, insurgents or radical religious elements • Types of military operations are likely to be HADR, peace-keeping, conventional war-fighting; all would be complicated within a mega-city; urban terrain acts as an equaliser for combatants • Military operations are likely to be joint and/or coalition-based • Unable to attain desired ratio of war-fighters to population; difficult to breach • There would be little kinetic effect, but potentially focus on specific aspects with more surveillance • Considerations include standard of living as it relates to potential for disease propagation • Access to communications and energy sources may become important in trying to isolate the affected area • Information warfare and management of public perception are

Wildcard scenario	Average impact score / 30	Effects on Australia, military operations and logistics
		prevailing factors; awareness of possible unintended consequences of military operations is vital • Sustainment over prolonged periods would be very challenging
2. Global war with loss of satellites	22.7	• This scenario entails strong focus on national defence; it is unlikely that military forces would be sent anywhere else • Important consideration is the ability of the national manufacturing infrastructure to adapt to military needs • Loss of satellites should be considered only as a complicating factor; the major focus would be on conduct of general war • A more significant factor is the likelihood of cyber attacks • A lot of currently used ADF technology does not depend on satellites, which reduces the potential impact of satellite warfare • Equipment that is GPS-enabled (including some types of ammunition, computers, and satellite navigation technology) becomes dead weight; reverse logistic chain may be required to bring the equipment back • Local systems and networks will still operate, but with loss of connectivity back to the major Defence business systems • Useful property for ICT systems is the ability by operate independently but synchronise when opportunity presents itself • Recent trend to transition to technology-enabled processes presents a vulnerability, as the ability to 'go back to basics' has been partially lost
3. Global supply chain crisis	26.5	• Immediate effect is the requirement for suppliers to shift routes, making their operations less financially viable • The cost of goods is likely to rise, with requirement to prioritise resources; civilian requirements can be expected to take precedence • In the longer term, disruption of shipment of goods may lead to stock-piling and scavenging due to resource shortages • Adaptability of infrastructure becomes important, as is the case for Wildcard 2; potential to switch to local production and to alternative forms of fuel would be significant • Back-up reserves would become important, keeping in mind that Australia doesn't have substantial oil reserves • There would be an immediate coalition-led response to resolve the situation
4. Weaponised nano-technology with swarming	20.0	• Overall effects will depend on maintaining a technological edge, the product life-cycles and organisational adaptability • There may be a shift towards obsolescence of large military platforms • There may be a shift in targets to civilian infrastructure and agriculture • Maritime environment is likely to be the first instance of exploitation of this technology • Disruption to the fundamental nature of the battle space may not happen due to simultaneous evolution and technological 'leap-frogging' of countermeasures; hence the technological advantage enjoyed by nations employing such technology is likely to be short-lived • Development of this type of capability is likely to require significant resources and be backed by multinationals • Potential applications include lightweight, strong, self-repairing materials
5. Self-aware AIs	23.5	• It is extremely difficult to forecast or predict what might happen with the advent of self-aware AIs

Wildcard scenario	Average impact score / 30	Effects on Australia, military operations and logistics
		• The rate of change may be very rapid, - potentially measured in minutes • The AIs may be difficult to control, with broad non-state effects; ability to shut these down would become important • Efforts to control AIs may mean disruption of large number of ICT-enabled services • One needs to consider how the physical infrastructure for AIs is made • Identification of decision points and ability to detect the occurrence of a self-aware AI become important • On the other hand, there are great opportunities for exploiting AI technology for logistic planning • There are also ethical considerations in taking the humans out of the loop, especially where using AIs for warfare • Ability to switch to non-technology based processes may become important
6+7. Climate change shocks and resource wars[2]	19.7	• Access to and availability of resources will change, including access to water, land, etc. • Continuity of fuel supplies is likely to become a major problem • Systems relying on oceans for sustenance are likely to fail with rapid changes and losses of ecological systems • Major coastal infrastructure is likely to be lost, thus exacerbating mass-migration • Mass-migration and rising sea levels will bring a focus on the littoral and amphibious operations due to increased tensions and fragility of state boundaries • The number of concurrent operations and their tempo can be expected to increase significantly due to regional instability and increase in number and severity of natural disasters • Military operations are likely to involve HADR, border control, resource protection, development of oil and natural gas reserves • Consideration would be given to use of 'soft' vs 'hard' power with political intervention and aid potentially reducing the requirement for military operations; this may involve creation of 'enclaves' and incorporation of neighbour states • Land mass of Australia may become desirable to other nations • Similarly to other wildcards, there may be a requirement to change to non-technology based processes • Technology may play a part e.g. in synthetic production of food
8. Pandemic	Not scored[3]	• Health facilities may become overwhelmed • Potential for breakdown of social structures as panic leads to stock-piling and self-isolation attempts • Provision of energy, food, water and medications may be disrupted • Global travel would be restricted, affecting supply chains • Globally, we have fairly robust monitoring systems and countermeasure procedures for these types of events; however, the physical connectivity across the globe (through rapid travel) and over-population make the pandemic scenario more likely • Defence would probably only have involvement in assisting the local authorities with enforcement of curfews and exclusion zones

[2] Wildcards 6 and 7 were discussed together during the workshop due to their similarities in effects
[3] Wildcards 8 and 9 were not scored due to time constraints

Wildcard scenario	Average impact score / 30	Effects on Australia, military operations and logistics
		• There would be commitment to look after own population before other nations (as would be the case for other nations as well); this also means that all countries would be stock-piling treatment medications for their own citizens first • Within mega-cities, the vector would be difficult to suppress if a hygienic environment cannot be maintained • Any military response would be coordinated with global organisations such as the World Health Organisation (WHO) • Communication and education efforts would become very important
9. Major geological/meteorological event[4]	Not scored	• Immediate loss of life and infrastructure with large number of wounded and trapped people; health facilities are likely to be overwhelmed • Disruption of key infrastructure: water, electricity, gas, sewage, ICT • Long-term climate instability with severe winters caused by ash cloud with large regions becoming un-inhabitable

The only clear outlier in the impact scores for the wildcard scenarios is global supply chain disruption, which got consistently high impact scores across all aspects of the scenario. This situation was generally considered damaging to Australia due to lack of adaptable indigenous manufacturing capability and oil refining capability. Interestingly, disruption of global supply chains is also a logical consequence of several other wildcard scenarios such as pandemic, major geological/meteorological events, or climate change shocks. Statistical treatment of the results is not meaningful in this instance due to the small number of respondents.

The discussions of national and military implications of the selected wildcard scenarios emphasize the importance of communication and sustainment in urban, littoral and amphibious environments. Furthermore, national dependence on the global supply chain for basic services suggests significance of self-sustainment for power and energy, food and water production. In some scenarios, a lot of ICT and other technologies are disrupted, making it important to maintain an ability to 'go back to basics'. Discussions of technological wildcards, such as nano-technology emphasize the importance of maintaining technology edge and awareness.

4.4.3 Implications for Technology Assessment

In terms of assessing the usefulness of new technologies, the key points presented above should be added to the list of desired characteristics. This is shown in Table 13, comprising a further refinement of Table 9 in which the additional characteristics are added in italics.

An additional discussion point that was repeatedly voiced during the workshops is the importance of organisational flexibility and adaptability in responding to rapidly changing conditions. This would require a change in outlook, adjustment of organisational structures and processes, and consideration of various vested interests.

[4] Wildcard 9 was not discussed in great detail due to time constraints

Table 13: Refined list of enduring logistic effects and desired technology effects[5]

Logistic Function	Sub-functions	Desired technology effects
Supply	• Warehousing • Procurement • Demand forecasting • Inventory management and provisioning • Disposal of materiel • Waste disposal and management	• Reduce stockholding and resupply requirements • Reduce dependence on limited transportation platforms • Facilitate force self-sustainability • Facilitate rapid surge capability • Reduce dependence on global supply chains • Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability • *Enable distributed, in situ generation of sustenance, power and energy* • *Reduce national dependence on global supply chains*
Movements and Transport	• Preparation and planning • Terminal operations, including loading, unloading and cross-loading • Distribution: transport of personnel and materiel	• Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability • *Facilitate distribution in urban, amphibious and littoral environments*
Materiel Engineering and Maintenance	• Control of design, inspection, testing • Condition monitoring, calibration, servicing • Classification as to serviceability/engineering certification • Repair • Rebuilding • Modification • Reclamation • Overhaul • Recovery • Salvage/cannibalisation • Evacuation	• Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability • Facilitate access to specialist support • Reduce maintenance requirements
Infrastructure Engineering and Maintenance – Sustainability Support	• Vertical and horizontal construction: planning, constructing and maintaining infrastructure • Provision of essential services • Obtaining resources in theatre • Waste disposal and recycling	• Improve robustness of critical infrastructure and systems • Provide power and energy as well as other key services in a distributed manner • Reduce reliance on ICT connected systems for essential services • Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability • Facilitate access to specialist support

[5] Italicised entries indicate further refinement from Table 9.

Logistic Function	Sub-functions	Desired technology effects
Personnel Support Services	• Personnel administration • Postal services • Welfare services • Management of POW • Messing • Accommodation • Catering • Laundry • Shower services • Support to mortuary affairs	• Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability
Health Services	• Prevention of injuries • Treatment of injuries • Casualty evacuation	• Extend evacuation options and time windows for casualties • Replace humans where possible, especially for dangerous and traumatic tasks • Replace humans for specialist tasks • Enhance human capability • Facilitate access to specialist support • Facilitate prevention, diagnosis and treatment of psychological trauma • Facilitate detection, identification, protection and treatment in relation to hazardous substances • Facilitate cross-exposure control measures • Reduce personnel exposure to environmental extremes
Command and Control	• Logistic intelligence analysis in support of the Common Operating Picture • Maintaining situational awareness • Business intelligence and modelling for decision support • Tactical/operational/strategic planning • Tactical/operational/strategic communication • Control and coordination of specific logistic functions through Logistic Information Systems (LIS) • Development, application and measurement of doctrine, policy, structures, processes • Contract management	• Maintain or improve situational awareness through gathering, transmission and analysis of data • Facilitate tailoring of logistic effects • Facilitate decision support for strategic/operational/tactical planning and C2 • Enable communication across extended distances • Facilitate preparedness for deployment • Enhance human capability • Facilitate data processing by operators and decision-makers • Facilitate communication across cultural/language barriers • Facilitate access to specialist support • *Operate without ICT connectivity or with intermittent ICT connectivity* • *Facilitate communication in urban, amphibious and littoral environments*
Capability Life-Cycle Management (in support of force modernisation and preparedness)	• Identifying capability gaps • Defining capability requirements • Acquiring and integrating capability • Managing fleet in service: rotation, deep maintenance, modification, monitoring fleet health status • Disposal of capability	• Maintain or improve situational awareness through gathering, transmission and analysis of data • Facilitate tailoring of logistic capability • Facilitate decision support for strategic planning and C2 • *Maintain technological edge*

5. Is the Technology Better than the Current Solution?

5.1 Desired Characteristics for Logistic Operations

Doctrinally, the enduring desirable qualities for logistics are responsiveness, simplicity, economy, flexibility, balance, foresight, sustainability, survivability, cooperation. At the same time, the key characteristics of balanced logistics are commonly described as velocity over mass, footprint optimisation, total asset visibility, and reliable delivery [1]. We took these considerations as the key measures for comparing a new technology to existing solutions.

5.2 Implications for Technology Assessment

In considering whether a new Technology XYZ is better than an existing solution, we took the desired characteristics for logistic operations and formulated them in the form of an additional checklist:

- Does the technology increase responsiveness?
- Does it reduce the cost?
- Does it increase flexibility and agility?
- Does it reduce the logistic footprint?
- Does it improve sustainability?
- Does it facilitate foresight, situational awareness, and total asset visibility?
- Does it increase sustainability and robustness of logistic operations?
- Does it facilitate cooperation?
- Does it support decentralised execution?
- Does it improve interoperability?
- Does it support deployability?

So, a technology that facilitates one or more of the logistic functions listed Table 13 would be assessed as an improvement on the current solution if it also provides a positive answer to one or more of the above questions. This, in turn, would be weighed against the cost of the technology and the associated FIC requirements.

6. How Much Does it Cost?

6.1 Fundamental Inputs to Capability

To take a holistic approach to cost assessment, we can make use of the established FIC framework (FIC) [19]:

- **Personnel**: recruiting and individual training requirements, maintenance of core skills, workforce requirements
- **Organisation**: appropriate organisational structures and competencies, as well as C2 arrangements
- **Collective training**: requirements for combined, joint, single-service and unit-level training
- **Major systems**: consideration of significant platforms, equipment fleets and operating systems
- **Supplies**: provision of particular stocks within specified readiness notice and requirements for reserve stock
- **Facilities and training areas**: facility infrastructure required to support the new capability both at home base and in deployed locations
- **Support**: infrastructure and services integral to maintenance of the capability in Australia and worldwide
- **Command and control**: C2 mechanisms, doctrine, security, processes and procedures

These elements provide a comprehensive framework for considering potential integration costs for new technologies.

6.2 Types of Expected Costs

Some of the expected costs with introduction of new technologies have been previously identified in a more detailed impact assessment study [20]. They are reproduced below with some generalising adjustments for a generic emerging technology.

1. **Non-recurring acquisition costs**
    a. Purchase of technology components
    b. Development of technology
    c. Modification of technology
    d. Initial spare parts supply
    e. Engineering (including advanced engineering)
    f. Installation and assembly

   g. Testing/trials
   h. Certification
   i. Technology integration.

2. **Recurring acquisition costs**
   a. Ongoing spare parts supply
   b. Specialised tools and equipment
   c. Other relevant equipment
   d. Software licensing
   e. Software updates
   f. Technology maintenance
   g. Insurance
   h. Disposal
   i. ICT infrastructure running/ maintenance costs (where applicable)
   j. Signal/bandwidth management (where applicable).

3. **Initial and ongoing administrative costs**
   a. Labour
   b. Administration
   c. Program monitoring
   d. Contract management
   e. Travel
   f. Documentation development
   g. Documentation distribution
   h. Use of facilities
   i. Associated supplies and support.

4. **Initial and ongoing training costs**
   a. Training of operators and training of trainers
   b. Associated supplies and support
   c. Use of facilities
   d. Certification and maintaining qualifications.

5. **Initial and ongoing R&D costs**
   a. Research
   b. Trials and pilot studies
   c. Monitoring and data analysis

d. Optimisation studies

e. Further development of the technology.

6. Initial and ongoing support costs

a. Information Technology (IT) support (where applicable)

b. Technical Support

c. Engineering support.

7. Ongoing fleet maintenance costs

a. Overall maintenance costs

b. Preventive maintenance

c. Corrective maintenance (including due to secondary damage)

d. Unnecessary maintenance

e. Unplanned maintenance

f. Module replacement

g. Mid-life upgrade/deep maintenance

h. Outsourced/contracted repairs.

8. Ongoing data management costs (where applicable)

a. Data collection

b. Data transmission

c. Data storage

d. Data analysis

e. Data security management

f. Data security breaches

g. Data purchase from the manufacturer.

9. Operational logistics costs

a. Transportation of spares

b. Urgent transportation of spares

c. Transportation of equipment/ vehicles

d. Recovery of equipment/ vehicles

e. Inventory holding and management.

6.3 Implications for Technology Assessment

The R-TAF process does not extend to the development of detailed cost-benefit models for new technology that would consider every part of type of associated expense listed in the previous section. We would expect such detailed assessment to occur at the next stage of detailed impact assessment studies. For the purposes of a rapid assessment, we condensed the cost considerations discussed above into the following four considerations:

1. Estimate of the expected technology development costs based on the Technology Readiness Level (TRL)
2. Estimate of the expected technology acquisition costs based on unit cost
3. Consideration of key technology integration requirements
4. Consideration of key maintenance requirements.

We expect that even without detailed numbers, examination of these four points is sufficient to provide an indication of the scale of financial expenditure for the organisation. Further cost-benefit modelling would, of course, be essential should the new technology be deemed suitable for detailed impact analysis.

7. Rapid Technology Assessment Framework

7.1 Finalised R-TAF for Land logistics

This document follows the process of exploration that we used to develop a requirement–centric approach to assessing the usefulness of emerging technologies. For our horizon scanning team, this work translates into a systematic checklist based on several reference lists that will be used to analyse and present key information regarding new technologies. This checklist is presented below with a worked example following in the next section.

1. **Is the new technology useful to logistic operations?**
   - Does the new technology enable required logistic effects? – ref. List A
   - Does it achieve desired effects for expected and extreme operational environments? – ref. List B
   - Does it have desired characteristics for expected operational environments? – ref. List C
2. **Is the new technology better than the current solution?**
   - Does the new technology increase responsiveness of logistic operations?
   - Does it reduce cost of logistic operations?
   - Does it increase flexibility and agility?
   - Does it reduce or optimise the logistic footprint?
   - Does it improve sustainability and robustness?
   - Does it facilitate situational awareness and total asset visibility?
   - Does it enable decentralised execution of mission?
   - Does it improve interoperability and deployability?
3. **What are the costs and FIC requirements for the new technology?**
   - What are the expected technology development costs based on TRL?
   - What are the expected technology acquisition costs?
   - What are the key technology integration requirements?
   - What are the key maintenance requirements?

List A: Enduring Logistic Effects

Supply
- Warehousing
- Procurement
- Demand forecasting
- Inventory management and provisioning
- Disposal of materiel
- Waste disposal and management

Movements and Transport
- Preparation and planning
- Terminal operations, including loading, unloading and cross-loading
- Distribution: transport of personnel and materiel

Materiel Engineering and Maintenance
- Control of design, inspection, testing
- Condition monitoring, calibration, servicing
- Classification as to serviceability/engineering certification
- Repair
- Rebuilding
- Modification
- Reclamation
- Overhaul
- Recovery
- Salvage/cannibalisation
- Evacuation

Infrastructure Engineering and Maintenance
- Vertical and horizontal construction: planning, constructing and maintaining infrastructure
- Provision of essential services
- Obtaining resources in theatre

- Waste disposal and recycling

Personnel Support Services

- Personnel administration
- Postal services
- Welfare services
- Management of POW
- Messing
- Accommodation
- Catering
- Laundry
- Shower services
- Support to mortuary affairs

Health Services

- Prevention of injuries
- Treatment of injuries
- Casualty evacuation

Command and Control

- Logistic intelligence analysis in support of the Common Operating Picture
- Maintaining situational awareness
- Business intelligence and modelling for decision support
- Tactical/operational/strategic planning
- Tactical/operational/strategic communication
- Control and coordination of specific logistic functions through Logistic Information Systems (LIS)
- Development, application and measurement of doctrine, policy, structures, processes
- Contract management

Capability Life-Cycle Management

- Identifying capability gaps
- Defining capability requirements
- Acquiring and integrating capability
- Managing fleet in service: rotation, deep maintenance, modification, monitoring fleet health status
- Disposal of capability

List B: Desired Effects for Expected Operational Environments

Supply

- Reduce stockholding and resupply requirements
- Reduce dependence on limited transportation platforms
- Facilitate force self-sustainability
- Facilitate rapid surge capability
- Reduce dependence on global supply chains
- Replace humans where possible, especially for dangerous and traumatic tasks
- Replace humans for specialist tasks
- Enhance human capability
- *Enable distributed, in situ generation of sustenance, power and energy*
- *Reduce dependence on global supply chains for Classes 1 and 3*

Movements and Transport

- Replace humans where possible, especially for dangerous and traumatic tasks
- Replace humans for specialist tasks
- Enhance human capability

- *Facilitate distribution in urban, amphibious and littoral environments*

Materiel Engineering and Maintenance
- Replace humans where possible, especially for dangerous and traumatic tasks
- Replace humans for specialist tasks
- Enhance human capability
- Facilitate access to specialist support
- Reduce maintenance requirements

Infrastructure Engineering and Maintenance
- Improve robustness of critical infrastructure and systems
- Provide power and energy as well as other key services in a distributed manner
- Reduce reliance on ICT connected systems for essential services
- Replace humans where possible, especially for dangerous and traumatic tasks
- Replace humans for specialist tasks
- Enhance human capability
- Facilitate access to specialist support

Personnel Support Services
- Replace humans where possible, especially for dangerous and traumatic tasks
- Replace humans for specialist tasks
- Enhance human capability

Health Services
- Extend evacuation options and time windows for casualties
- Replace humans where possible, especially for dangerous and traumatic tasks
- Replace humans for specialist tasks
- Enhance human capability
- Facilitate access to specialist support
- Facilitate prevention, diagnosis and treatment of psychological trauma
- Facilitate detection, identification, protection and treatment in relation to hazardous substances
- Facilitate cross-exposure control measures
- Reduce personnel exposure to environmental extremes

Command and Control
- Maintain or improve situational awareness through gathering, transmission and analysis of data
- Facilitate tailoring of logistic effects
- Facilitate decision support for strategic/operational/tactical planning and C2
- Enable communication across extended distances
- Facilitate preparedness for deployment
- Enhance human capability
- Facilitate data processing by operators and decision-makers
- Facilitate communication across cultural/language barriers
- Facilitate access to specialist support
- *Operate without ICT connectivity or with intermittent ICT connectivity*
- *Facilitate communication in urban, amphibious and littoral environments*

Capability Life-Cycle Management
- Maintain or improve situational awareness through gathering, transmission and analysis of data
- Facilitate tailoring of logistic capability
- Facilitate decision support for strategic planning and C2
- *Maintain technological edge*

List C: Desired Technology Characteristics for Expected Operational Environments

Physical Characteristics

- Lightweight
- Robust to physical stress and range of environmental conditions
- Small and portable
- Rapidly deployable: easy to procure/access, pack and transport
- Easy to repair/ replace
- Distributed in nature

Functional Characteristics

- Multi-functional, flexible, adaptable
- Scalable in effect
- Incorporating redundancies
- Sensor-enabled and networked
- Predictive
- Working within limited bandwidth availability
- Resistant to cyber attacks

Interface Characteristics

- Designed with awareness of cultural sensitivities
- Cognisant of operator state
- Reactive to operator state
- Protective/ preventive
- Enabling of decision support and rapid response
- Standardised for joint and coalition operations
- Interoperable with a range of opportunistic platforms

Figure 3: Finalised Rapid Technology Assessment Framework for Land logistics

This is a necessarily client-centric checklist, but similar approaches can be easily expanded to other military domains with the aim of providing quick one-page summaries of relevant technology characteristics.

7.2 Example of R-TAF Application for Hybrid Generators

The checklist developed by our team is meant to be a guide for doing quick preliminary analysis of emerging technologies. In this section we demonstrate what the outcome may look like using the example of hybrid generators – a technology of interest highlighted in our previous horizon scanning report [21]. Application of the R-TAF checklist to this technology based on information provided in [22] is presented below.

Description
Hybrid generator technology based on racks of batteries coupled to diesel generators and (if available) solar panels. Generation of power is shifted between the components so as optimise fuel consumption.

FlexGen hybrid generator system developed by Earl Energy is currently being used by US Department of Defence (DoD) (image via [22])

Is the technology useful to Land logistics?

- Enabled logistic effects:
  - *Provision of electricity to deployed bases*
- Enabled desired effects for expected and extreme operational environments:
  - *Significant reductions in stockholding and resupply requirements for fuel against a small increase in requirement for holding spare batteries*
  - *Reducing dependence on limited transportation platforms for resupply of fuel*
  - *Facilitating force self-sustainability by reducing fuel usage*
  - *Reducing maintenance requirements and replacement costs for diesel generators due to increased equipment life*
- Compliance with desired characteristics for expected operational environments:
  - *Hybrid generators for military use are designed to be robust and operate in a range of environmental conditions*
  - *Size and weight is similar to currently used generators*
  - *This technology can be used in a distributed fashion*

Is the technology better than the current solution?

- Does it increase responsiveness of logistic operations?
  - *Not directly*
- Does it reduce cost of logistic operations?
  - *Yes, through significant reductions in fuel usage. Recent trials of Earl Energy's FlexGen generators in Afghanistan achieved reductions of over 50% by ensuring that generators run at optimum efficiency.*
  - *Flow-on effect is reduction of costs associated with fuel transportation.*
  - *Additional savings can be expected in reduction of maintenance and replacement requirements for the generators which would be run at optimum efficiency.*
  - *This is somewhat offset by associated additional cost of high-quality batteries with a*

high cyclic rating required for this system.

- Does it increase flexibility and agility?
  - *Not directly*
- Does it reduce or optimise the logistic footprint?
  - *Yes, through reduction of fuel usage while providing for increased electricity requirements associated with greater number of computers, radios and vehicles.*
- Does it improve sustainability and robustness?
  - *Yes, through reduction of fuel usage and subsequent reduction in fuel transportation requirements. An indirect effect is reducing vulnerability of transport convoys to interdiction.*
- Does it facilitate situational awareness and total asset visibility?
  - *N/A*
- Does it enable decentralised execution of mission?
  - *N/A*
- Does it improve interoperability and deployability?
  - *Earl Energy's FlexGen generators are being used by US DoD with initial trials done in Afghanistan.*
  - *Generators for military purposes are produced to particular specifications and to fit existing platforms for transportation.*

How much does it cost?

- Technology TRL and development requirements:
  - *TRL 8-9 technology that is already being used on operations; no further R&D investment is required to mature the technology to usable level.*
- Expected acquisition costs:
  - *Price per generator to be confirmed.*
  - *Additional cost is in purchase of high-quality batteries with a high cyclic rating.*
- Key technology integration considerations:
  - *Product purchased for military purposes can be expected to be tailored to required specifications and platforms.*
  - *Technology integration is likely to involve minor adjustments to maintenance and repair requirements, but by and large the hybrid generators can replace the current ones without any major changes to associated equipment or processes.*
- Key maintenance requirements:
  - *Maintenance requirements are expected to be reduced due to optimal operation of the equipment.*
  - *Extra maintenance requirement is in periodic replacement of batteries.*

The above example shows how a systematic approach based on Land logistics requirements may be used to analyse new technologies. This approach will be trialled further during technology horizon scans conducted for ADF Land logistics in 2015.

8. Discussion

8.1 Validity of Study Design

The purpose of the study conducted by our team was to develop a systematic approach for what is frequently an intuitive process: identifying technologies that may be of interest to the military client. The approach also provided a balancing, requirements-driven checklist to the largely technology-driven process of horizon scanning.

However, in the process of generating the R-TAF we need to acknowledge the existence of several judgement-based elements. In particular, refinement, verification and validation of many of the framework elements were conducted in a workshop setting with military logistic SMEs. We had six participants for the first part of the workshop and three for the discussion of wildcard scenarios. Such small group size precludes any statistical treatment of the results and means that the generated data cannot be considered representative of the opinions of larger populations. This is partly offset by selection of participants, who were Army Headquarters staff with significant experience in logistic planning. All logistic elements were represented within the group, with a slightly greater emphasis on engineering.

Analyst-driven elements of the study included selecting the operational and wildcard scenarios for discussion, and translating the collected information into implications for technology assessments. We will seek feedback from workshop participants and clients regarding these elements of the framework and incorporate it into future iterations of the framework and horizon-scanning studies.

8.2 Validity of the Generated R-TAF

We believe that the resulting R-TAF and associated checklists allow a systematic, common-sense approach to assessing and describing emerging technologies that may be of interest to the client. However, the framework does not prioritise any particular elements; this is left to the client for consideration. It also deliberately avoids any numerical scoring. We would judge such scoring systems to be largely irrelevant and potentially misleading when assessing technologies with vastly differing applications. Instead, the focus is on providing a concise word picture that summarises the most relevant aspects of the emerging technologies for the client.

There are also additional considerations that are not addressed within the R-TAF but that are likely to influence the technology selection process. These include legal, ethical and cultural issues surrounding the use of particular technologies. Furthermore, the framework also doesn't take into account the national and global implications of the new technologies and any potential conflicts with vested interests of business and political groups.

We do not intend for the presented framework to be considered its final version. Review of the client requirements and the technology scans need to be conducted in an iterative manner with continuing refinement and incorporation of updates from key strategic documents such as the Defence White Paper.

8.3 Further Considerations

One additional consideration that was consistently voiced during the SME workshops is the importance of organisational flexibility and adaptability in dealing with any significant changes such as those presented in the wildcard scenarios. This inevitably requires consideration of the various layers of authority and of the influential parties with vested interests, which was outside the scope of our study.

9. Conclusion and Recommendations

This document follows the development of a systematic Rapid Technology Assessment Framework that can be applied as part of the horizon scans for emerging technologies. This particular framework focuses on the Land logistics operations, although similar approaches can be adopted for other military domains. It balances what is largely a technology-driven horizon scanning process with careful consideration of the client needs.

The R-TAF seeks to ensure that the technologies recommended for further detailed impact studies are:

- Useful to client's requirements in the context of expected operational environments
- Improve on the current solution in terms of the desired characteristics for logistic operations
- Cost-effective across a range of measures

The developed framework and associated checklists will be used for subsequent technology scans for Land logistics and will continue to be refined and updated.

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References

1. Joint Logistics Command (2011) *Australian Defence Doctrine Publication 4.0 Defence Logistics, 2nd Edition*. Australian Government Department of Defence.
2. Australian Government Department of Defence (2012) *Australian Defence Doctrine Publication (ADDP) 3.0 Campaigns and Operations, 2nd Edition*.
3. Directorate of Plans - Army (2014) *The Australian Army: An Aide-Memoire*. Australian Army Headquarters, April 2014.
4. Australian Government Department of Defence (2013) *Defence White Paper 2013*. Commonwealth of Australia.
5. *The Future Logistics Concept 2035 (Draft)*. (2014) Strategic Logistics Branch, Joint Logistics Command, Vice Chief of the Defence Force Group, October 2014.
6. Modernisation and Strategic Planning Division (2014) *Future Army. Building on Beersheba (Presentations)*. Australian Army Headquarters, August 2014.
7. Directorate of Plans - Army (April 2014) *Australian Army: Our Future. Army Modernisation Update, Version 2*. Australian Army Headquarters, Editor. Canberra.
8. *The Millennium Project - Futures Research Methodology*. (2014), Glenn, J. C. and Gordon, T. J., Editors.
9. Strategic Futures Team (2001) *A Futurist's Toolbox. Methodologies in Futures Work*. Performance and Innovation Unit, Center for Strategic Studies and Management in Science, Technology and Innovation (CGEE), Brazil, September 2001, 22 pages.
10. Petersen, J. L. (1997) *Out of the blue: Wild cards and other big future surprises: how to anticipate and respond to profound change*. 1st ed, Arlington Institute.
11. iKnow Community *Wildcards*. [Accessed 31 October 2014]; Available from: http://community.iknowfutures.eu/
12. Barber, M. (2006) Wildcards - Signals from a future near you. *Journal of Futures Studies* **11** (1).
13. Dorsett, P. (2014) *Future Logistics Operating Environment 2035 (Draft)*. Strategic Logistics Branch, Joint Logistics Command, Vice Chief of the Defence Force Group.
14. US Office of Naval Research (2011) *Naval Science and Technology Strategic Plan*.
15. New Zealand Landcare Research (2008) *Future Scenarios - Urban Edition. Wildcards.*
16. US Department of Defence (2014) *2014 Climate Change Adaptation Roadmap*.
17. Schuckmann, S., Linz, M., von der Gracht, H. ,Darkow, I.-L. (2011) Delphi-based Disruptive and Surprising Transformation Scenarios on the Future of Aviation. In: *4th International Seville Conference on Future-Oriented Technology Analysis (FTA),* Seville: 12-13 May 2011.
18. Pradera, F. and Alderton, M. (2014) *Medical Countermeasure Product - Alternatives Paper*. DSTO-GD-0812, Defence Science and Technology Organisation, April 2014.
19. Capability Development Group (2014) *Defence Capability Development Handbook 2014*. Australian Government Department of Defence.
20. Ivanova, K., Gallasch, G. E., Rajesh, S. ,Manning, C. (2014) *Condition Based Maintenance Technology Impacts Study for the Military Land Environment*. DSTO-RR-0404, Defence Science and Technology Organisation,, August 2014.
21. Ivanova, K. and Gallasch, G. E. (2014) *Horizon Scan of Emerging Technologies for ADF Combat Service Support Elements*. DSTO-CR-2014-0243, Defence Science and Technology Organisation,, July 2014.

22. LaMonica, M. (2014) Hybrid Generator Would Cut Military Base Fuel Costs in Half. *IEEE Spectrum*, 3 February 2014 [Accessed 14 January 2015]. Available from: http://spectrum.ieee.org/energywise/aerospace/military/hybrid-generator-would-cut-military-base-fuel-costs-in-half.
23. Inayatullah, S. (2013) Future Studies: Theories and Methods. In: Junquera, F. G. (ed.) *There's a Future: Visions for a Better World*. BBVA Group, available via https://www.bbvaopenmind.com/en/book/there-is-a-future-visions-for-a-better-world/, 30 pages
24. Tran, T. A., Daim, T. (2008) A taxonomic review of methods and tools applied in technology assessment. *Technological Forecasting and Social Change* **75** 1396-1405.
25. Koivisto, R., Wessberg, N., Eerola, A., Ahlquist, T., Kivisaari, S., Myllyoja, J., Halonen, M. (2009) Integrating future-oriented technology analysis and risk assessment methodologies. *Technological Forecasting and Social Change* **76** 1163-1176.
26. Lee, A. M., Bereano, P.L. (1981) Developing technology assessment methodology: Some insights and experiences. *Technological Forecasting and Social Change* **19** 15-31.
27. Roessner, D., Frey, J. (1974) Methodology for technology assessment. *Technological Forecasting and Social Change* **6** 163-169.
28. Dortmans, P. J., Curtis, N.J. (February 2004) *Towards an analytical framework for evaluating the impact of technology on future contexts*. DSTO-TR-1554.
29. Webb, R. N., Goodman, L., Staples, B., Hughes, S. (June 2006) Identifying potential implications of technologies on military and security operations. In: *CCRTS*.
30. Brandes, F. (2009) The UK technology foresight programme: An assessment of expert estimates. *Technological Forecasting and Social Change* **76** 869-879.
31. Helmer, O. (1967) *Systematic use of expert opinions*. RAND Corporation.
32. Defence Evaluations and Research Agency (DERA) (2000) *Military Judgement Panel Support Guide*. August 2000.
33. Nguen, M.-T. and Dunn, M. (2009) *Some Methods for Scenario Analysis in Defence Strategic Planning*. DSTO-TR-2242, Defence Science and Technology Organisation, 53 pages.
34. Joint Logistics Group (2006) *Australian Defence Doctrine Publication 4.1 Capability Support, 1st Edition*. Australian Government Department of Defence.
35. Joint Logistics Command (2013) *Australian Defence Doctrine Publication 4.2 Logistic Support to Operations, 2nd Edition*. Australian Government Department of Defence.
36. Modernisation and Strategic Planning Division (2014) *Future Land Warfare Report 2014*. Directorate of Future Land Warfare, Australian Army Headquarters, April 2014.
37. Boey, S., Dortmans, P. and Nicholson, J. (2014) *DSTO Foresight Study*. Defence Science and Technology Organisation.
38. Dexter, P. (2013) *Input to the Future Land Warfare Report 2014*. DSTO-CR-2014-0240, Defence Science and Technology Organisation.
39. US Army (2014) *The Mega City. Operational Challenges for Force 2025 and Beyond*. Unified Quest Deep Future Wargame 2030-2040.
40. Hoffman, F. and Garrett, P. (2014) The Great Revamp: 11 Trends Shaping Future Conflict. *War on the Rocks*, 8 October 2014 [Accessed 10 October 2014]. Available from: http://warontherocks.com/2014/10/the-great-revamp-11-trends-shaping-future-conflict.
41. Strategic Plans Branch (2014) *Army Research and Development Plan 2014*. Australian Army Headquarters, Australian Government Department of Defence.

42. Manyika, J., Chui, M., Bughin, J., Bisson, P. ,Marrs, A. (2013) *Disruptive technologies: Advances that will transform life, business, and the global economy*. McKinsey & Company Global Institute, May 2013, 176 pages.
43. Defence Science and Technology Organisation (2014) *Future Cyber Security Landscape. A Perspective on the Future*.
44. Australian Defence Force (2013) *Global Change Seminar Series.* Defence Preparedness Branch, Joint Capability Coordination Division, Vice Chief of the Defence Force Group

Appendix A. Overview of Forecasting Methods

A.1. Introduction

Perhaps the most important thing to know about forecasting studies is that they do not aim to predict the future, and if they do, they are usually not very good at it. The purpose of forecasting is the examination of a range of possible futures so as to support development of more robust long-term policies, encourage an anticipatory mindset and better understand threats and opportunities [8]. A survey of futures forecasting methods reveals a large number of conceptual approaches as well as specific techniques. A good overview of the epistemological underpinnings and general-level discussion of futurist works is provided by Inayatullah [23]. A comprehensive discussion of over twenty various methods has been developed by the Millenium Project [8].

Evaluation of technologies as a specific type of forecasting has been a growing field over the last four decades [24] with variable terminology used to describe studies related to future technologies. For example, Future-oriented Technology Analysis (FTA) can be used as a common term for technology foresight, technology forecasting and technology assessment [25]. Technology assessment can be defined as: determining the trends of technological change and their implications for the relevant social sectors; attempting to forecast potential future trends and their consequences; and making decision recommendations so as maximise desired benefits and minimise negative effects, in line with normative policies [26]. This latter description is implied in references to technology assessment, which is the focus of this document.

A.2. Overview of Forecasting Approaches and Methods

Although various techniques have been developed to facilitate forecasting and technology assessment, it is generally accepted that due to the breadth and variations in technology assessments, there isn’t just one readily-replicable method [26, 27]. A chronological overview of methods and tools for technology assessment is provided by Tran and Daim [24], with further description of various approaches in [27]. Various techniques used for technology assessments are outlined in [25] along with groupings according to their characteristics (Popper’s diamond) and functions as shown below.

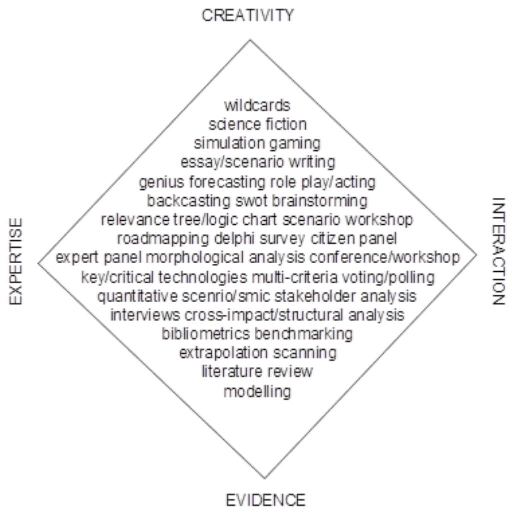

Figure 4: Technological forecasting methods grouped by characteristics (adapted from Ref. [25], p. 1165)

Table 14: Functional groupings for technological forecasting methods (adapted from Ref. [25], p. 1166)

Understanding	Synthesis & Models	Analysis & Selection	Transformation	Actions
Scanning	Gaming	SWOT analysis	Back-casting	Priority lists
Bibliometrics	Scenario planning	Multi-criteria analysis	Road-mapping	Critical/key technologies
Literature review	Wildcard analysis	Cross-impact analysis	Relevance trees	R&D planning
Interviews	Weak signals	Prioritisation/Delphi	Logic Charts	Action planning
Trends/Drivers Indicators	Modelling	Scoring/rating	Linear programming	Operational planning
Systems analysis	System simulation	Benefit/cost/risk analysis	Strategic planning	Impact assessment

Slightly different functional groupings and lists can also be found in [28, 29], as outlined in the tables below. These present different approaches to the collection and structuring of information for future technology studies.

Table 15: Functional groupings for future scenario development (adapted from Ref. [29], p. 15)

Collecting judgements	Forecasting time series/ other quant. measures	Understanding linkages between events, trends, and actions	Determining a course of action in presence of uncertainty	Portraying alternate plausible futures	Understanding state of future	Tracking changes and assumptions	Determining system stability
Genius	Econo-metrics	System Dynamics	Decision Analysis	Scenarios	State of the Future Index	Environ-mental scanning	Non-linear techniques
Delphi	Trend Impact Analysis	Agent Modelling	Road Mapping	Futures Wheel		Text mining	
Futures Wheel	Regression Analysis	Trend Impact Analysis	Technology Sequence Analysis	Simulation Gaming			
Group meetings	Structural Analysis	Cross Impact Analysis	Genius	Agent Modelling			
Interviews		Decision Trees					
		Futures Wheel					
		Simulation Modelling					
		Multiple perspectiv es					
		Causal Layered Analysis					
		Field Anomaly Relaxation					

Table 16: Forecasting methods for future innovation in military context (adapted from Ref.[28])

Extrapolation of current trends	Group consensus	Historical analysis	Generation of alternate futures
Environmental scanning: systematic review of literature/SME opinions	Delphi – individual experts are surveyed, results collated and returned to participants for further refinement	Analysis of technological drivers and their impact on military operations	Field Anomaly Relaxation (FAR) – creating scenario space that spans the range of activities that might evolve in the future
Emerging issues analysis: identifying pertinent trends	Determining key indicators necessary for realisation of particular technologies		Discrepancy analysis and comparison of futures using pair-wise comparison of FAR factors
	Steps for considering integration of technologies		

A.3. Descriptions of More Common Approaches

A.3.1 Delphi Questionnaires

Delphi was conceived by the RAND corporation in 1940's and 1950's and has been used by the Japanese government to conduct foresight surveys since 1971 [30]. An overview of the Delphi survey principles is provided by Helmer [31]. In its simpler version, the SMEs are asked to write down their estimates independently. These estimates are then revealed (without identifying the respondents) and debated openly. The SMEs are then asked to provide their (potentially revised) estimates again. The median of the responses is accepted as the group's decision and quartile range is used as a measure of group consensus[31].

Delphi questionnaires encourage a controlled debate, unaffected by personalities of the participants. More often that note, the groups of SMEs move toward consensus; otherwise, the reasons for conflicts of opinion are clarified [8].

A.3.2 Workshops

Workshops are an alternative way of eliciting SME opinions in a face-to-face setting. They have the advantage of assignment of dedicated time and space for more extensive discussions with faster development of the discussion itself. Guidelines for conduct of workshops were taken from the Military Panel Judgement Panel Support Guide [32], which reviews in detail the possible sources of bias and relationships within the group and provides an overview of twenty nine different techniques such as brainstorming and hypergames. In particular, the 'round robin' and 'free for all' brainstorming techniques were used for most parts of our workshops. A multi-voting system was used to conduct impact assessment of wildcards.

A.3.3 Scenarios

Scenarios can be used to explore a broad set of future operating conditions that the user may have to deal with [8]. This approach was first officially used by RAND and later by Royal Dutch Shell and other multinationals [9]. Scenarios help understand future problems, challenges and opportunities, as well as identify knowledge gaps and assumptions. Good scenarios are plausible, internally consistent, creative, anchored and sufficiently interesting, exciting and realistic to elicit strategic responses [8, 9].

Several approaches to scenario construction can be found in [8, 9, 33]. The key elements of the method involve identification of the external drivers, key issues and variables, and checks of the generated scenarios for relevance, consistency and comprehensiveness. Scenarios can be used to generate discussion of policy options and to develop anticipatory awareness in the users. Some of the supporting techniques include brainstorming, workshops, Delphi, Morphological Analysis (MA), Batelle approach, Field Anomaly Relaxation (FAR), and Cross-Impact Analysis; these are discussed in more detail in [33].

The advantage of scenarios is their adaptability and ease of communicating complex information. This makes them a useful tool for facilitating debate and clarifying assumptions. Furthermore, they are useful in developing plans that are viable over a wide range of possible futures [8, 9].

A.3.4 Morphological Analysis

A generalised form of Morphological Analysis (MA) was proposed by Fritz Zwicky in the 1940s as a method for structuring and investigating the total set of relationships in multi-dimensional problem complexes with inherently non-quantifiable socio-technical characteristics [8]. The method involves development of a parameter space of the problem complex (the 'morphological field') and defining relationships between its variables on the basis of internal consistency. The solution space is marked out based on configurations that are consistent, possible, viable, practical, interesting, etc. Usually, 8-12 well-chosen scenario configurations suffice to cover all of the cells in the scenario field [8].

There are many ways of using MA for various purposes, and one of the applications is construction of scenarios through identification of the key parameters and their possible configurations.

A.3.5 Wildcards

'Wildcards' are essentially events with low probability of occurrence, but a high impact [8, 9]. A comprehensive methodology for wildcards can be found in [10] with shorter overviews in [8, 9]. Wildcards are useful in overcoming the blind-spots and shortcomings of trend-driven foresight with a more open-minded approach that helps recognise the alternatives [8]. They can also help develop early warning systems and monitor for indicators of the change [9]. Wildcards can be classified in different ways, with three basic types [8]:

- Events that are known and relatively certain to occur without knowing the timing (such as the next earthquake)
- Events unknown to the public that could be discovered by consultation with the right experts (such as the impacts of climate change)
- Intrinsically unknowable events

The methods of identifying wildcards include brainstorming, expert interviews, surveys, analysis of historical analogues, and science fiction [8]. Once identified, the wildcards are assessed for relevance and impact. An example of impact calculation is outlined in [8]:

- Vulnerability (V): How vulnerable is the system to the changes brought about by the event?
- Timing (T): Does the event take place sooner rather than later?
- Opposition (Op): Are there groups who will oppose these changes?
- Power Factor (P): At what level does the event affect individuals?

- Reach (R): How broad is the effect (local, national, global)?
- Outcome (O): How unpredictable is the outcome?
- Rate of change (ΔC): Wild Cards come fast
- Impact Factor (I_{AI}): The Arlington Impact Index is a sum of the impact factors of the rate of change, reach, vulnerability, outcome, timing, opposition, and power factor:

  $$\Delta C + R + V + O + T + Op + P = I_{AI}$$

- Quality Factor: Is the impact positive or negative?

Within this study, a modified version of this impact assessment approach was used for the chosen wild-card scenarios.

A.3.6 Focused Technology Scans

The objective of a technology scan is to identify new developments that can challenge past assumptions or provide new perspectives about future threats or opportunities [8]. The general process is outlined in Figure 5 (adapted from [8], ch.2, p. 4).

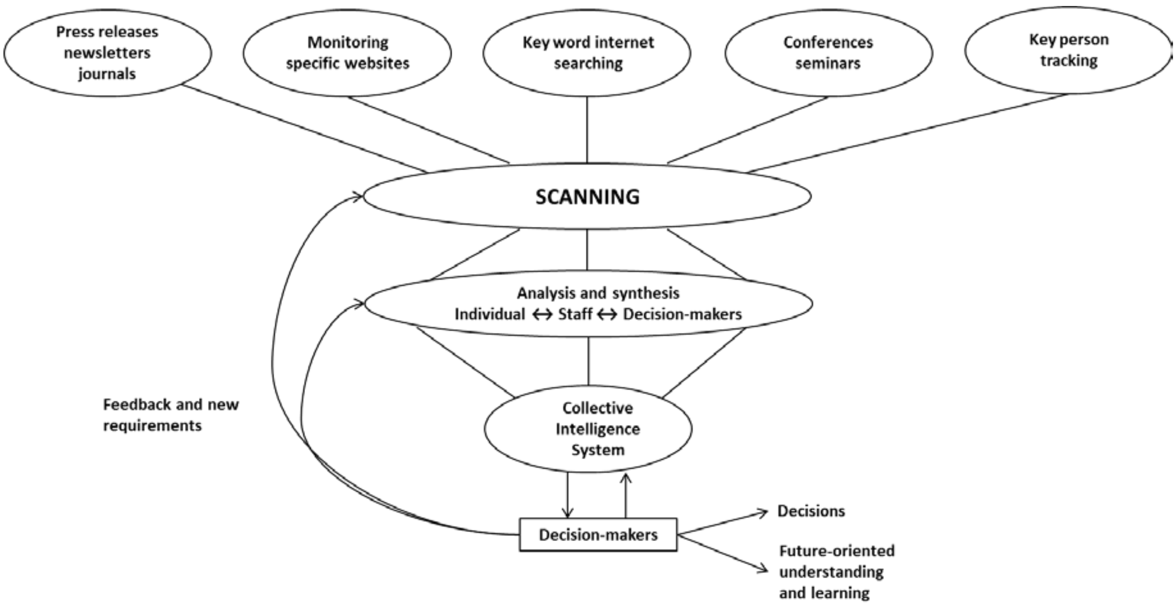

Figure 5: Process for a focused technology scan (adapted from [8], ch.2, p. 4)

The 'Feedback and new requirements' link allows the system to 'learn' how to perform better and produce the most cogent knowledge while avoiding information overload. This type of technology scan is used by our study team for horizon scanning of emerging technologies.

Appendix B. Overview of the Land logistics System

Doctrine suggests three domains to be considered: control, information and physical. Alternatively, military logistic systems can be thought of as encompassing physical systems, C2 systems, information systems, processes and personnel. The quantitative aspects of logistics include quantities/weights/dimensions, times and distances, consumption and attrition rates, and system performance data (transport, storage, handling metrics) [1].

From a slightly different perspective, logistic functions can be separated into acquisition, sustainment and distribution. Acquisition encompasses needs, requirements and acquisition phases of the capability life-cycle. Sustainment covers the provision of resources necessary to support operations and achieve preparedness (including in-service and disposal phases of the capability life-cycle). Distribution refers to the means by which logistics support is delivered to the users, including transport, warehousing, inventory management and control [1].

Further dimensions of ADF logistics are support to capability and support to operations [1]. Support to capability covers acquisition and support to in-service capabilities, as well maintaining their readiness for operations. It can be viewed in terms of the Fundamental Inputs to Capability (FIC): personnel, organisation, collective training, major systems, supplies, facilities, support, command and management. It is also commonly described in terms of the capability life-cycle phases [1]:

- **Needs**: identification of capability gaps
- **Requirements**: defining capability in terms of functions, standards and conditions; transforming capability needs into costed, defined solutions
- **Acquisition**: acquiring the capability solution, establishment and entering the capability into service with full systems integration
- **In-service**: management of individual FICs in order to operate, support and modify the capability as required
- **Disposal**: withdrawal of the capability from service and its disposal or redeployment.

Operations support is needed to deploy, redeploy and sustain a force during operations with six key operational subsystems [1]:

- C2 and communications that extend across the entire system
- Personnel support services, including health services
- Transport and movements
- Materiel engineering and maintenance
- Supply
- Infrastructure engineering and maintenance.

ADDP 4.1 [34] lists the key functional areas of logistics slightly differently as supply, movements and transport, equipment maintenance and engineering, infrastructure maintenance and engineering, personnel support services, and health services.

Figure 6 outlines the relationship between capability support and operational support.

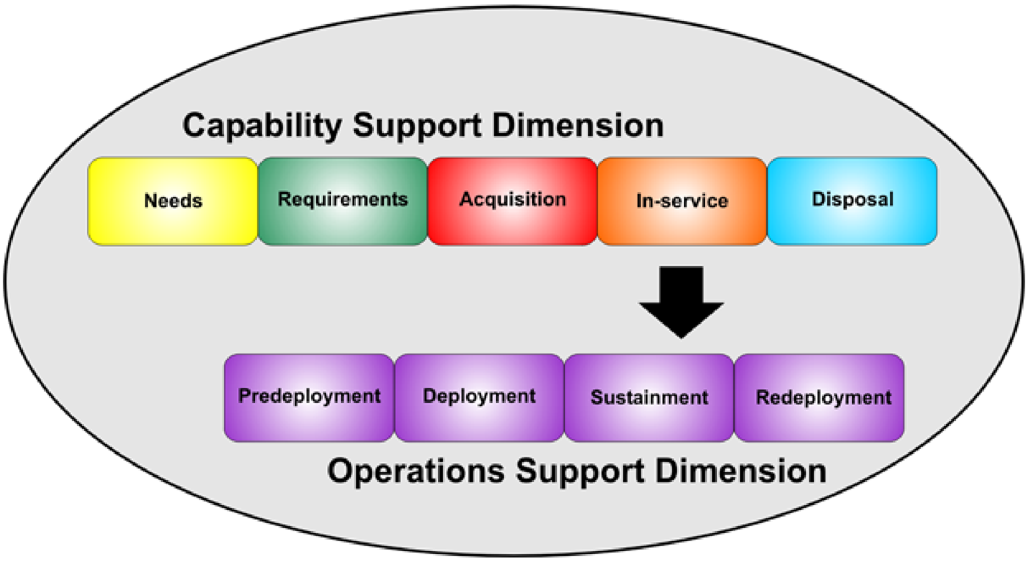

Figure 6: Defence logistic support dimensions [35] p. 1-2

These various approaches to structuring were considered in structuring of the land logistic effects, with greater emphasis being placed on the functional breakdown.

Appendix C. Draft List of Enduring Logistic Effects

A draft list of enduring logistic effects was constructed as part of this study based on review of logistics documents. It is detailed in Table 17. The list was further refined during workshops with military logistic SMEs, with the final version presented in Section 4.1.

Table 17: Draft list of enduring logistic effects based on doctrine review

Logistic Function	Sub-functions
Supply[6]	• Warehousing • Procurement • Distribution • Demand forecasting and provisioning • Inventory management • Disposal of materiel • Waste disposal and management • Catering • Laundry • Shower services • Support to mortuary affairs
Movements and Transport[7]	• Preparation and planning • Control and coordination • Terminal operations, including loading, unloading and cross-loading • Transport of personnel • Transport of materiel
Materiel Engineering and Maintenance[8]	• Control of design, inspection, testing • Condition monitoring, calibration, servicing • Classification as to serviceability/engineering certification • Repair • Rebuilding • Modification • Reclamation • Overhaul • Recovery • Salvage/cannibalisation • Evacuation
Infrastructure Engineering and Maintenance	• Mobility support: reconnaissance, route clearance, bridging, obstacle reduction, underwater mine/explosives clearance • Counter-mobility support: construction of obstacles, conduct of demolitions • Survivability support: construction of physical protection measures, fire and emergency response, identification and protection from hazardous material, support to deception measures, advice on signature management • Sustainability support: planning/constructing/maintaining infrastructure, provision of essential services (power, water, sewage, bulk fuel, heating/ventilation/ AC), obtaining resources in theatre, waste disposal and recycling • Geospatial support: acquiring and managing geospatial information, producing visualisation

[6] The sub-functions are applicable across ten classes of supply: 1 – Subsistence, 2 – General Stores, 3 – POL, 4 – Construction Stores, 5 – Ammunition, 6 – Personal Demand Items, 7 – Principal Items, 8 – Medical and Dental Stores, 9 – Repair Parts, 10 – Non-Military Stores.

[7] Movements and transport are used in tactical, operational and strategic contexts; transport modes include sea, water, road and air.

[8] Types of engineering are commonly listed as mechanical, electronic, aviation, electric, and general.

Logistic Function	Sub-functions
Personnel Support Services	• Personnel administration • Postal services • Welfare services • Prisoners management • Messing • Accommodation
Health Services[9]	• First response and evacuation with clinical sustainment • Triage, resuscitation, diagnostics and surgery • Casualty holding, treatment of sick and wounded • Allied health support: psychology, physio, pharmacy, dental, OEHS • Health materiel management • Health administrative functions • Military medicine specialties: submarine and underwater medicine, aerospace medicine, CBRN medicine • Health intelligence analysis in support of the CHP • Health C2 including management of patient flow and evacuation chains
Command and Control	• Maintaining situational awareness • Data analysis for decision support • Tactical/operational/strategic planning • Tactical/operational/strategic communication • Development of governance mechanisms: doctrine, policy, structures, processes
Support to Capability	• Identifying capability gaps • Defining capability requirements • Acquiring and integrating capability • Managing fleet in service: rotation, deep maintenance, modification, monitoring fleet health status • Disposal of capability

[9] Health services encompass support pre-deployment for force preparation, during deployment for force maintenance, and post-deployment for evaluation and rehabilitation. The operational health system is often described in terms of the roles of care from first aid and Role 1 (primary health care) through to Role 3/4 hospital facilities.

Appendix D. Analysis of Global Trends

Elicitation of possible future operational scenarios requires consideration of the current global and local trends across the physical, social and technological domains. Examination of several forecasting and strategic guidance documents suggests a number of trends outlined in Table 18. These are classified into physical, technological and human/political/social domains. They are further structured in trends, effects on the nature of threat, effects on operational environment and effects on logistic operations. A causal map of the trends and their key effects is shown in Figure 7 and Figure 8.

Table 18: Summary of global trends and their key effects

Trends	Effects on the nature of threat	Effects on operational environment	Effects on logistics
Physical environment			
• Climate change and rising sea levels [16, 36] • Proximity of large urban centres to the coast [5, 13, 36] • Crowded environment, urbanisation and emergence of mega-cities [36-39]	• Damage to shore-based infrastructure by rising seas [5] • Mass migration[38] • Concerns over global food, water and energy security [4, 36-38] • Civilian infrastructure as targets [38] • Rising numbers of IDPs, governance issues, crime and economic issues in mega-cities [37-39]	• Increasing significance of maritime strategy, amphibious operations and littoral capability [5, 36, 40] • Increasing significance of urban operations [36, 40] • Requirement for tracking and reduction of emissions [13]	• Multiple entry points [5] • Requirement for on-shore/off-shore logistics and ship-to-shore connectors [5] • Alternative energy transportation modes and larger transportation modes [13] • Diverse, distant, concurrent operations with distributed ground forces [40] • Shift from fixed bases to dynamic presence [40] • More modular force structure and development of small unit capability [40, 41] • Distribution-based logistics requiring adequate lift capacity, and quick resolution of any distribution flow issues [41] • Increasing significance of balancing mass and velocity in logistics [5, 41]
Human, social and political environment			
• Ageing population and increasing focus on health and well-being [37] • Increasing economic and geopolitical significance of fossil fuels [42] • Increasing number of failed and failing states with proliferation of non-state actors [4, 36, 43] • Increasingly ad hoc partnerships [40] • Increasing recognition of the significance of	• Increasing focus on security and stability in local region [4, 36] • Shifts between symmetric and asymmetric warfare [41] • Susceptibility to global supply chain disruptions with greater requirement for security measures [4, 5, 13, 36, 37] • Cascading effects of any strategic shocks [13]	• Rising number and prevalence of alternative energy solutions [5] • Greater requirement for HADR operations [36] • Requirement for greater investment in human capital such as language and cultural competence [40] • Requirement to form and manage highly fluid organisational and information-sharing arrangements [40]; alignment of practices/technologies/sharing support arrangements [5, 36] • Requirement to develop capabilities	• Supply chains becoming targets for asymmetric effects [5] • 'Last km' remaining the toughest from capacity and force protection perspectives [41] • Requirement for 'hardening' of logistic capabilities [41] • Reliance on commercial services and global supply chains [5] • Capacity demands on population supply and protection [5]

political/human/cultural/social factors [4, 40] • Financial austerity [4, 36, 38] • Globalisation of supply chains leading to reduced local manufacturing and better standardisation/efficiencies [4, 5, 13]		with the greatest utility across the broadest range of operational scenarios [5] • Whole-of-Government approach and use of standing offer arrangements [13] • Alliance with US [5]	
Technological environment			
• Increased digitisation and complexity of inter-connected systems [4, 13, 36, 43] • Cyber-enabled national enterprises [4, 13, 36, 38, 43] • Counter-trend in 'off-the-grid' movement [38] • Real-time access to events and emergence of 'e-democracy' [38, 43] • Big Data and Internet of Things [5, 37, 38, 43] • Emerging and disruptive technologies [5, 38, 40] • Falling costs and barriers to technological innovation and reverse-engineering [4, 40] • Reduced investment in education, S&T and R&D in western nations	• Increased 'attack surface' and difficulties in threat definition with ICT security lagging ICT [36, 43] • Critical dependence on ICT leading to vulnerability to cyber threats [4, 13, 38, 43] • Increased likelihood of deliberate disruptions of ICT systems [38] • Emergence of protean enemy with ambiguous and unpredictable capability using unconventional warfare with hybrid options [36, 38, 40] • Vulnerability of fixed bases with large noise and emission signatures [36] • Diminishing technological advantage of western nations [4, 13]	• Increasing dependence on ICT systems not under ADF control [43] • Requirement for improvement in information management; handling/exploitation/assurance processes; resilient and protected networks; signature and bandwidth management [4, 5, 36] • Requirement for timely acknowledgement and adaptation to emerging threats [13, 43] • Increasing reliance on satellite technology [36] • Integration of manned and unmanned systems changing the nature of the battle-space [40] • Constant challenges to the ability to adapt equipment and tactics [40] • Requirement to control access to lethal technology [36] • Shift towards use of cost-imposing measures e.g. simple deception measures, mobile-basing, directed energy [40]	• Increasing situational awareness across a range of processes [13] • Dependence on constant connection to supply information systems [41] • Requirement to avoid over-reliance on ICT systems and loss of basic logistic skills [5, 36] Requirement for ability to operate in degraded ICT environments [36] • Training requirements to develop relevant technical competence [5, 13, 36] • Requirement for capability to support more technologically advanced platforms and systems [5] • Requirement for secure design and supply chain process for ICT hardware and software [43] • Challenges in data-security, warehousing, processing and provision of supporting infrastructure [5] • Requirement for standard planning system across echelons, consumption factors, policies, capabilities, geography, etc. [41] • Need for data-analysis capability [5] • Potential labour savings through automation [5]

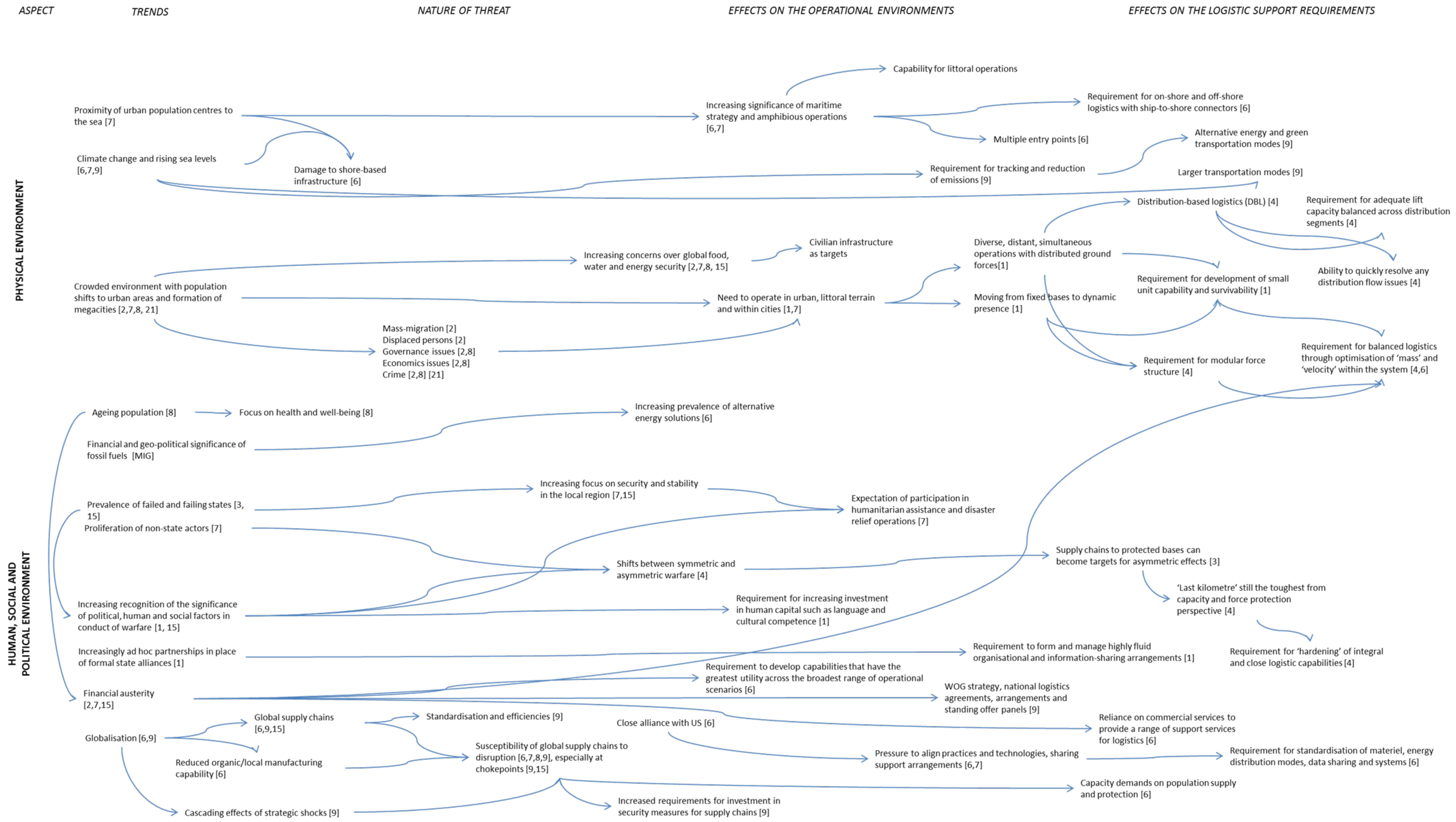

Figure 7: Causal map for global trends and their key effects (physical environment; human social and political environment)

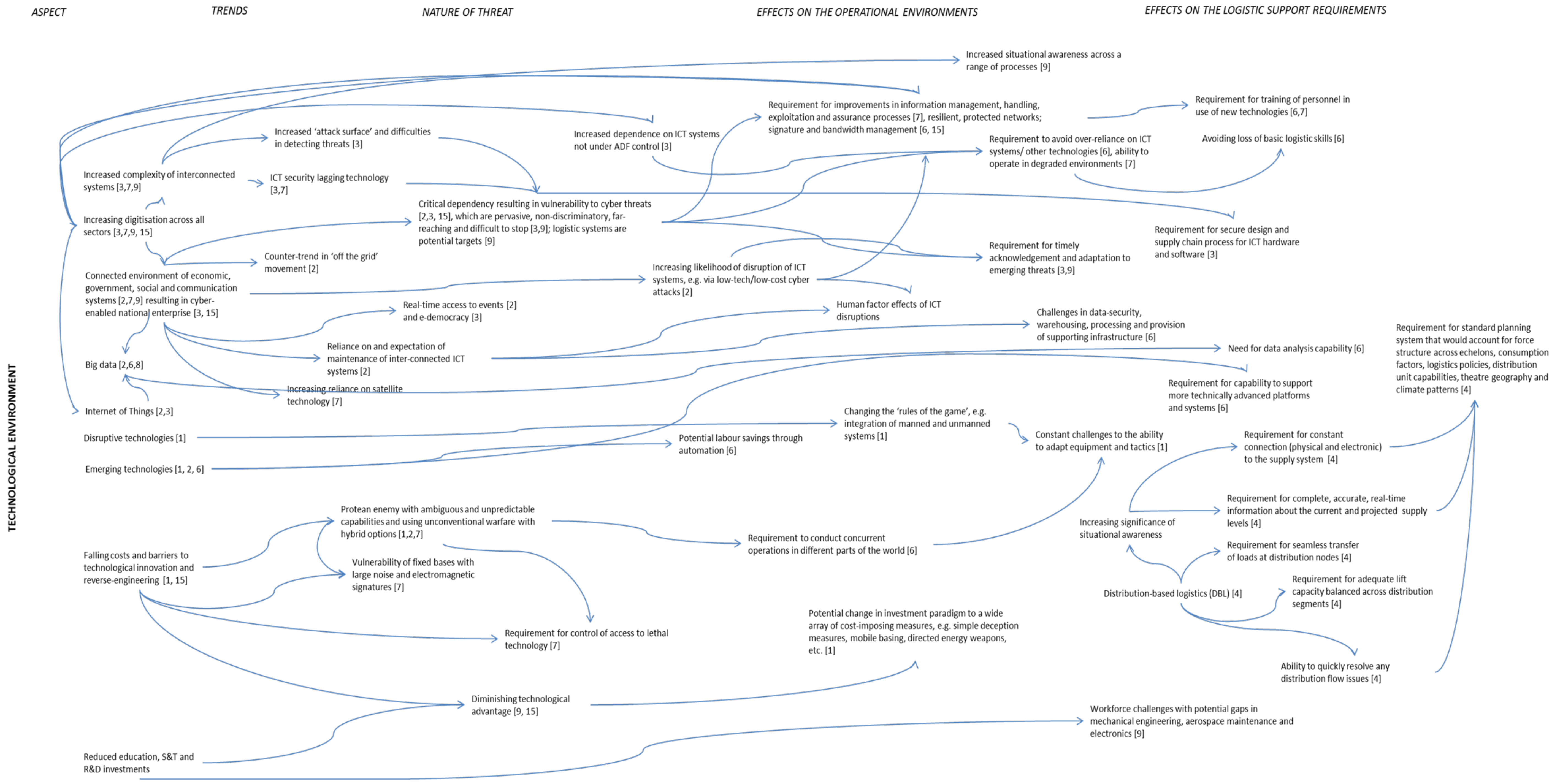

Figure 8: Causal map for global trends and their key effects (technological environment)

Appendix E. Identified Wildcard Scenario Candidates

The identified wildcard candidates and references are summarised within groupings according to their origin using the STEEP sectors: Society, Technology, Economy, Environment, Politics [8]. They are further worded so as to group together various causes leading to the same or similar event. In the lists below, the citing of 'A' is an indication that the wildcard was the result of analysis of the global trends picture. Shortlisted candidates are highlighted in bold.

Society and Politics Sector

- **Instability/crime/revolt leading to violent outbreaks within a regional mega-city [A][8] with population no longer recognising political authority [11]**
- Lack of S&T and R&D investment [A][11] leading to significant loss of technological edge and professional skill-base [8]
- Major shift in social/ethical values [11] and outbreak of altruism [8] leading to greater stability and economic prosperity in the region and reduction of military operations [8]
- Growth of religious environmentalism [8]
- Collapse of the United Nations [8]
- End of the nation state [8]
- **Global war hostilities [12] with disruption of global satellite systems [A]**

Technology Sector

- **Terrorist attacks on networks and physical routes leading to global supply chain crisis [13][A]**
- Hacking and whistle-blowing acts, as well as mass decryption of passwords, mobile phone accounts, IPs, etc. [8, 11, 13] resulting in radical transparency [11]
- Major cyber warfare event [11] leading to collapse of global communication networks affecting trade, commerce and Internet [8, 11, 12][A]
- Targeted infiltration of military logistic information systems and falsification of information [A]
- Communication satellites breakdown [12]
- Large-scale electromagnetic pulse (EMP) warfare irreparably knocks out all electronic circuits, wiping out internet, telecommunications, cars and appliances [15]
- **New energy source such as commercially available cold-fusion[8, 13] or efficient renewables leading to global energy revolution [8, 17] [15].**
- **Swarming/nano-technology becoming weaponised [A][8, 14] leading to significant changes to the nature of the battle-space [A]**
- Development of directed energy weapons [14]
- Major chemical attack on the country [A]

- Major biological attack on the country [A][8] [18]
- Major nuclear attack on the country [A] [8, 11, 12]
- Wide-ranging and lengthy disruption of national electrical supply [8]
- **Self-aware machine intelligence is developed [8]**
- **Humans directly interface with the internet [8] and 'immortality' is achieved through mind transfer to computing substrate [11]**
- Mind-reading technology is developed [11]
- Breakthroughs in human cognition/human performance technologies [14]
- Additive manufacturing technology leading to 'fabbing society' [17]
- Nanotechnology industry breakthroughs result in immediate increase in life-expectancy and child-bearing years by 50% leading to baby-boom [15]
- Technology breakthroughs in recycling reduce building costs by 75% as well as minimising waste stream materials [15]

<u>Economy Sector</u>

- **Increasing life-expectancy [8], aging population and over-population, and climate change leading to food, water, energy and environmental resource shortages [A] [8, 11, 12, 14]**
- World-wide famine as rust fungus affects rice and grain crops and reduces harvests on an ongoing basis [15]
- De-globalisation [11] and transition to barter trade [11];
- Intensified worldwide economic shocks leading to fundamental re-thinking of free trade flows and to strict protectionism [17]
- Very harsh restrictions on emissions and fossil fuel consumption [A]
- Collapse of a major economy such as US [8, 12] or China [11] leading to global financial crisis [A], global banking and stock crisis, loss of confidence, massive inflation and collapse of the world trade [15]
- **Global resource wars increase energy costs, especially for liquid fuels; actual continuity of supply becomes a major problem with frequent interruptions [15]**
- No-carbon economy world-wide [8]
- Hackers blackmail key financial institutions in the country [8]
- Food and energy import embargoes [12]
- Collapse of a major hydrocarbon exporting state affecting global energy supplies [13]

<u>Environment Sector</u>

- **Global climate change accelerates to tipping points leading to climate shocks, rising sea levels and mass migrations with a host of flow-on consequences [A] [8, 11, 13, 15, 16, 44]**

- **Large number of concurrent operations due to world-wide instability, mass-migration, and increasing number and severity of natural disasters at home [A]**
- **Epidemic/pandemic affecting the country's population [A] [8, 11-13, 15, 17, 18]**
- **Major geological/meteorological event, such as asteroid, volcanic eruption, large earthquake [8, 11-13, 15, 17]**
- The Earth's axis shifts [8]
- Collapse of world's fisheries/ Silent seas [8, 11]
- Bacteria becoming mostly immune to antibiotics [8]
- Arrival of extra-terrestrials/discovery of alien civilisation [8, 11, 13]
- A magnetic solar storm hitting the Earth and disrupting electricity supply [11]

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19. ABSTRACT
This report follows the development of a Rapid Technology Assessment Framework (R-TAF). The framework is designed to assist with preliminary analysis of emerging technologies. It provides a requirements-centric approach to technology assessment as a balancing effort to what is often a technology-driven horizon-scanning process. The framework outlined in this document focuses on military Land logistics applications, although similar principles can be applied to other military domains.

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